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5.0 APPENDIX

5.1 Study Area Descriptions

(Legal descriptions are based on the 5th Principal Meridian.)

Stand 1. Location: Winona Co., 5.5 mi. N of St. Charles, Whitewater State Park, Chimney Rock Bluff; NE¼ SE¼ Sec. 20, T 107 N, R 10 W. Topography: Steep hills, unglaciated, N 30° W aspect, 0–20% slope, ridgetop, rock outcrops, rocky soil. Vegetation: 60–70% canopy dominated by Juniperus virginiana (2–10" D.B.H.), Quercus alba, Q. borealis (0–14"), Ostrya virginiana, with grasses dominant in the understory; bare soil 10% excluding trails. Remarks: Maple-basswood climax vegetation on moist side slope. Survey records: April, 1834; at SE corner of Sec. 20, white oak (2", 10"), basswood (8"), and aspen (7") recorded as witnesses; at half section post between sections 20 and 21, white oak (8") and black oak (6") recorded; at NE corner of Sec. 20, bur oak (10", 12"), white birch (5"), and aspen (6") recorded; comments around the south and east sides of Sec. 20 include: "Land broken," "2nd [and] 3rd rate" (marginal or not suitable for agriculture), "very little timber," some in groves, hazel and shrub oak undergrowth, dead aspen on hillside.

STAND 2. Location: Jackson Co., 7 mi. N and 4 mi. W of Jackson, Kilen Woods State Park; W½ NE¼ Sec. 17, N¼ SW¼ Sec. 16, T 103 N, R 35 W. Topography: Mostly level land intersected by large draw with perennial stream; N aspect, 0–5% slope, upland above draw, good soil. Vegetation: 60% Quercus macrocarpa (1–20") with Ulmus americana (6–28") and Tilia americana; bur oak and basswood reproduction; much

Ribes americanum; no bare soil. Remarks: stand not open grown. Survey records: October, 1858; 23.00 ch. east between Sections 16 and 21 scattered bur oak bears NW and SE; at half section between 16 and 21, white oak (24"), bur oak (8") recorded; north between Sections 16 and 17, 15.00 ch. enter timber, 35.00 ch. leave timber, 40.00 ch. prairie vegetation; comments at the southeast corner of Sec. 17 include "surface rolling, prairie & timber, soil 1st rate. Timber mostly bur oak." North between Sections 16 and 17, "Surface rolling, prairie & timber, soil 1st rate;" oak, elm, ash, basswood, ironwood; between Sections 17 and 8, "Surface rolling, prairie, soil 2nd rate."

STAND 3. Location: Rock Co., 5 mi. N of Luverne, Blue Mounds State Park; NE¼ NW¼ Sec. 24, T 103 N, R 45 W. Topography: Rolling surface with rock outcrops, S 80° E aspect, 0-30% slope, creek bottom and adjacent side slope, rocky and sandy soil. Vegetation: 40% canopy of Fraxinus pennsylvanica (1-15") and Quercus macrocarpa (1-12"), oak reproduction, dense understory, primarily riparian habitat; 15% exposed rock. Remarks: Grazed in the past, now occasionally mowed; water impoundments on stream; some trees planted. Survey records: November, 1869; between Sections 13 and 24, 14 and 23, and 23 and 24, prairie land; comments include "Stony prairie," "slough," "prairie land;" no mention of trees. [note: subsequent reexamination of the area in another part of the park

showed mesic forest invading below a bluff and Rhus glabra and bur oak invading prairie on the top of the bluff.]

STAND 4. Location: Murray Co., 11 mi. NE of Slayton, Shetek State Park; SE¼ NE¼ Sec. 6, T 107 N, R 40 W. Topography: Rolling to level surface on bench above Lake Shetek, west aspect, 0–5% slope, sandy-gravelly soil. Vegetation: 40–50% canopy of mature Quercus macrocarpa (up to 36") and Fraxinus pennsylvanica (up to 28") with Ulmus americana and Acer negundo; shrub understory; no bare soil. Remarks: Oaks open grown; good reproduction of species other than oaks; herbaceous ground cover dense, perhaps the result of disturbance. Survey records: September, 1861; between Sections 6 and 7, "grove of scattering Br. Oak" and prairie vegetation; north between Sections 5 and 6 11.50 ch. "leave grove of shrubby bur oak; enter prairie," 19.00 ch., "small grove on slough," 56.50 ch. "hay marsh," 70.00 ch. "scattering of young timber," 74.00 ch. "brush," 76.00 ch. "cane slough;" 11.60 ch. north of southeast corner of sec. 6., bur oak (4", 10").

STAND 5. Location: Lyon Co., 14 mi. S of Marshall; NW¼ SW¼ Sec. 11, T 109 N, R 40 W. Topography: Rolling with draws and small seasonal streams; uplands above Cottonwood River; S 60° E aspect, 5–10% slope, upper slope. Vegetation: 50% canopy of Quercus macrocarpa (10–15"), shrubby understory of Xanthoxylum americanum, Symphoricarpos occidentalis, and

grasses; no bare soil. Remarks: Has been grazed in the past but not for at least 5 years; bur oaks do not have open grown appearance. Survey records: July-August, 1867; SW corner of Sec. 11, prairie; no trees mentioned between Sections 10 and 11; comments include "Surface rolling" and "Soil No. 1."

STAND 6. Location: Pope Co., 3 mi. NW of Glenwood; NE¼ SE¼ Sec. 28, T 126 N, R 38 W. Topography: Top of rolling hills, above marshland and lakes; N 70° E aspect, 0-5% slope, sand to loam soil. Vegetation: 60-70% canopy of Quercus macrocarpa (up to 12"), with understory of Acer negundo and Xanthoxylum americanum with good herbaceous ground cover; no bare soil (at least litter covered). Remarks: Stand cut over 20-30 years ago, since then not much disturbance; oak stump sprouts, some oak reproduction. Survey records: September, 1859; SE corner of Sec. 28, bur oak (6", 6", 6", 24"); north between Sections 27 and 28, 38.00 ch. "enter bur oak opening," 40.00 ch., bur oak (20", 20"), 42.50-56.55 ch. "wet marsh;" S edge of Sec. 28, 40.00 ch., prairie; comments include "Surface rolling" with prairie and "timber bur oak," "soil 1st rate" and "Surface hilly, prairie soil 2nd rate."

STAND 7. Anoka Co., East Bethel, Allison Savanna Nature Conservancy Area; NE¼ NE¼ Sec. 2, T 133 N, R 23 W. Topography: Rolling sand dunes; south aspect, 0-5% slope, upper slope. Vegetation: Oak savanna with Quercus macrocarpa and

Q. borealis dominant; understory predominantly prairie with occasional Corylus americana; 5% bare soil. Remarks: Some controlled burning in area, not in study plot area; gopher mounds and ant hills common; some blowouts and marshy areas. Survey records: November, 1856; NE corner of Sec. 2, black oak (11", 11"); south between Sections 1 and 2 at 41.50 ch. black oak (10"); comments include "Sand rolling," "3rd rate soil;" "Scattering black oak & bur oak;" "tamarack, and oak brush."

STAND 8, 9. Ottertail Co., 3½ mi. W of Urbank, Inspiration Peak State Park; SE¼ SW¼ Sec. 22 and NE¼ NW¼ Sec. 27, T 131 N, R 39 W. Topography: Hill above generally rolling country; hilltop and N 60° W aspect sidehill stands, slope 0%, 30%; gravelly soil. Vegetation: Stand 8 (hilltop)—Open stand of Quercus macrocarpa with shrub and prairie understory; bare soil 5%. Stand 9 (sideslope)—Closed stand of Quercus macrocarpa, Q. ellipsoidalis, and Ulmus americana with shrubby and herbaceous understory; no bare soil. Remarks: Hilltop dry, sideslope moist; the area was probably grazed in the past. Survey records: July, 1871; W between Sections 22 and 27, 40.10 ch. oak (14", 16"); SW corner of Sec. 22, oak (4", 6", 6", 6"); comments include "Surface very rolling;" "Scattered oak timber;" "Thick oak brush;" "Open brush land;" "Soil second rate."

STAND 10. Location: Hubbard Co., 3/4 mi. S of Hubbard;

W½ SE¼ SW¼ Sec. 29, T 139 N, R 34 W. Topography: Level land above slightly rolling topography; sandy soil. Vegetation: 70% canopy cover of Quercus macrocarpa (4-6", 25-30' tall), with a few Pinus banksiana; well developed shrub layer; no bare soil. Remarks: No visible results of fire although some oaks clumped at root collar; a few large open grown oaks present, but most of canopy was closed grown. Survey records: December, 1860; SW corner of Sec. 29, N pine (probably white pine) (20", 24"); east between Sections 29 and 32 from SW corner of Sec. 29, 24.00 ch. leave "timber & enter small prairie;" 40.00 ch. bur oak (6", 8"); comments include "Sand 3rd rate" and timber noted was "R & N pine [red and white] & tamarac."

STAND 11. Location: Mahnomen Co., 8½ mi. E of Mahnomen and ¼ mi. S; NW¼ NW¼ Sec. 5, T 144 N, R 40 W. Topography: Middle slope above small lake, E 20° aspect, 6% slope; moist sandy loam soil. Vegetation: Wet to mesic prairie with Andropogon gerardi (up to 4' tall), A. scoparius, Amorpha canescens, Petalostemum spp., and Solidago spp.; 2% bare ground. Remarks: Active gopher mounds being invaded by Symphoricarpos occidentalis; Populus tremuloides and Rhus glabra invading from upland; prairie unplowed but fall mowed annually. Survey records: September-October, 1874; comments include "rolling prairie," "first rate" soil. (See also Survey records, Stand 12.)

STAND 12. Location: Mahnomen Co., 8½ mi. E of Mahnomen and ½ mi. S; SE¼ SE¼ NE¼ and NE¼ NE¼ SE¼ Sec. 6, T 144 N, R 40 W. Topography: Hill above prairie and marsh land, E aspect, near top of hill, 3-20% slope; sandy loam soil. Vegetation: 60% canopy of Quercus macrocarpa (up to 20" X 50') with Tilia americana and Ulmus americana; well developed shrub layer; scattered forbs; no bare soil (litter covered). Remarks: Stand not disturbed for at least 25 years, and then only posts removed. Survey records: September-October, 1874; at SE corner of Sec. 6, oak (10", 14", 14", 20"), "timber oak & aspen;" at quarter corner between Sections 6 and 7, ash (10") and willow (4"), "timber elm, oak, & aspen;" S between Sections 5 and 6 from NE corner of Sec. 6, 44.00 ch. oak (6", 6"), timber "elm, oak, aspen, and sugar;" comments include "soil first rate" and "North ½ rolling prairie" and "South ½ timber."

STAND 13. Location: Norman Co., 4 mi. E of Syre and 1 1/8 mi. N; NW¼ SW¼ SW¼ Sec. 17, T 143 N, R 43 W. Topography: Level land on top of moraine ridge; gravelly soil. Vegetation: 40% canopy of Quercus macrocarpa with Populus tremuloides and Acer negundo; well developed shrub understory; no bare soil. Remarks: Abandoned homesite with open grown oaks. Survey records: July, 1871; SW corner of Sec. 17 is in prairie; comments include "Timber oak and aspen;" "Aspen, hazel & willow undergrowth;" "high peak, highest of area."

STAND 14. Location: Clay Co., 3½ mi. E of Glyndon and 1½ mi. S; SE¼ NE¼ Sec. 16, T 139 N, R 46 W. Topography: Level land; sandy gravelly soil. Vegetation: Mesic prairie with Andropogon gerardi, A. scoparius and associated species; no bare soil. Remarks: Large boulders on surface; never been plowed, but fall mowed annually; drainage ditches within 200 yards; shrubs and trees (including Cornus stolonifera [one individual 13 years old], Salix spp. [4 individuals 12 to 49+ years old], and Populus tremuloides) becoming established around rocks and in low places. Survey records: September, 1870; "level prairie."

STAND 15. Location: Polk Co., 1 mi. S of Fertile and ½ mi. W; Agassiz Dunes Nature Conservancy Area; W½ NE¼ Sec. 32, T 147 N, R 44 W. Topography; Sand dunes with all aspects, level to 40% slope, some old blowouts; very fine sand. Vegetation: Primarily Quercus macrocarpa (4-8" X 30') savanna with prairie understory and Populus tremuloides invading low areas; Juniperus horizontalis common; 5% bare soil. Remarks: The area has been grazed in the past, but not recently; very few active blowouts. Survey records: August-September, 1872; quarter corner between Sections 29 and 32, oak (10", 10"); NW corner of Sec. 32, oak (5", 6", 6", 8"); quarter corner between Sections 32 and 33, "Brush prairie;" comments on north side of Sec. 32, "Surface hilly and broken;" "Soil 2nd rate;" "Scattering oaks, patches of prairie & brush."

STAND 16. Location: Marshall Co., 3 mi. S of Karlstad; NE¼ SE¼ Sec. 5, T 158 N, R 45 W. Topography: Low, level, standing water in places during wet seasons: gravelly soil. Vegetation: 45% canopy of Populus tremuloides (4-7" X 55') with some Quercus macrocarpa (4-5" X 25'); dense shrub understory (4-7' tall); no bare soil. Remarks: Railroad immediately W of stand may influence water standing in wet seasons; not disturbed recently, but evidently in past (cause undetermined). Survey records: February-March, 1877; SE corner of Sec. 5, aspen (4", 5", 6", 7"); quarter corner between Sections 4 and 5, aspen (5", 6"); comments include "Land 2nd rate;" "Brush prairie & scattering aspen;" "Timber small aspen."

STAND 17. Location: Kittson Co., 5 mi. NE of Karlstad; NE¼ SW¼ Sec. 3, T 159 N, R 45 W. Topography: Flat land above marshes; sandy soil. Vegetation: 30% canopy of Quercus macrocarpa, with some small Populus tremuloides; shrub cover 30-40%; prairie ground cover; no bare soil. Remarks: Evidently this stand was cut over as evidenced by the Q. macrocarpa sprouts, but several mature oaks left; P. tremuloides also removed. Survey records: April, 1877; SW corner of Sec. 3 is "marsh land;" E from SW corner of Sec. 3, 20.00 ch. leave "open marsh enter tamarac;" 25.00 ch. leave "tamarac & enter oak;" 34.40 ch. aspen (10", 12"); quarter corner between Sections 3 and 4 is "marsh;" "upland 2nd rate [soil]." (Evidently the tamarack is between marsh and oak/aspen upland in this section).

5.2 Additional Vegetation Descriptions

5.21 Tree Reproduction and Shrub Data

Stand 2, Bur oak woods. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Fraxinus pennsylvanica	0	0	2	3	0.0938	3	10-20"	0	-
Ostrya virginiana	0	0	2	5	0.1562	2	4-20"	3	1.5-6'
Prunus virginiana	2	3	12	16	0.5000	11	4-36"	5	1-4'
Quercus macrocarpa	4	4	12	19	0.5938	16	4-10"	3	8"
Ribes cynosbati	4	14	29	44	1.3750	41	4-25"	3	3'
Symphoricarpos occidentalis	13	18	30	42	1.3215	28	6-36"	14	1-3'
Tilia americana	4	4	9	17	0.5312	8	4-6"	9	1-4'
Ulmus americana	1	2	8	10	0.3125	10	3-24"	0	-
Xanthoxylum americanum	9	14	24	39	1.2188	14	4-20"	25	1.5-7'

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

Stand 5, Bur oak woods. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Acer negundo	0	0	0	1	0.0312	1	24"	0	-
Fraxinus pennsylvanica	0	3	3	3	0.0938	3	18"	0	-
Prunus virginiana	0	0	0	2	0.0625	1	18"	1	4'
Quercus macrocarpa	0	2	2	5	0.1562	5	4-18"	0	-
Ribes cynosbati	38	97	151	218	6.8125	211	3-36"	7	3-5'
Symphoricarpos occidentalis	29	58	94	153	4.7812	149	6-20"	4	1.5-2'
Ulmus americana	1	3	3	3	0.0938	3	10-15"	0	-
Xanthoxylum americanum	1	2	4	10	0.3125	9	10-30"	1	4'

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

Stand 6, Bur oak woods. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Acer negundo	4	11	12	15	0.4688	8	6-60"	7	2-8'
Fraxinus pennsylvanica	8	12	23	37	1.1562	37	6-12"	0	-
Prunus virginiana	1	1	6	11	0.3438	8	6-48"	3	5-6'
Quercus macrocarpa	0	0	1	4	0.1250	3	2"	1	2'
Ribes cynosbati	3	12	18	30	0.9375	28	3-24"	2	1-4'
Rubus occidentalis	9	16	27	39	1.2188	39	12-24"	0	-
Symphoricarpos occidentalis	6	8	12	13	0.4062	12	6-24"	1	3'
Xanthoxylum americanum	3	10	15	31	0.9688	29	6-36"	2	3-4'

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

Stand 7, Bur oak savanna. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Quercus macrocarpa	1	2	2	8	0.25	0	-	8	0.5-6'

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

Stand 10, Bur oak woods. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Amelanchier humilis	6	10	11	26	0.8125	15	6-48"	11	3-6'
Corylus americana	12	26	40	84	2.6250	79	10-48"	5	5'
Crataegus rotundifolia	1	1	2	5	0.1562	5	10-36"	0	-
Lonicera canadensis	7	10	11	13	0.4062	13	4-36"	0	-
Prunus virginiana	3	6	16	35	1.0938	30	6-36"	5	2-6'
Rhus radicans	0	3	13	30	0.9375	30	6-18"	0	-
Rosa blanda	4	8	11	18	0.5625	17	6-48"	1	5'
Rubus strigosus	0	0	0	2	0.0625	2	12-24"	0	-
Symphoricarpos occidentalis	9	15	30	71	2.2188	61	6-48"	10	3-4'

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

Stand 11, Prairie. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Rosa arkansana	3	4	4	6	0.1875	6	6"	0	-
Symphoricarpos occidentalis	1	1	9	9	0.2812	9	6"	0	-

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

Stand 12, Bur oak woods. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Acer negundo	11	29	50	95	2.9688	93	2-24"	2	2'
Cornus racemosa	1	4	6	6	0.1875	7	30-48"	1	6'
Cornus stolonifera	0	0	3	3	0.0938	3	4-12"	0	-
Crataegus punctata	0	0	6	14	0.4375	13	3-30"	1	3'
Fraxinus pennsylvanica	2	2	7	9	0.2812	8	2-24"	1	6'
Populus tremuloides	0	0	2	2	0.0625	2	4"	0	-
Prunus virginiana	2	2	7	13	0.4062	9	2-42"	4	2-7'
Rhus radicans	10	40	71	119	3.7188	112	3-24"	7	1.25-2.5'
Rubus occidentalis	2	2	4	4	0.1250	4	12"	0	-
Sambucus pubens	0	3	3	4	0.1250	4	3-6"	0	-
Symphoricarpos occidentalis	13	16	23	30	0.9375	30	6-36"	0	-

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

Stand 15, Bur oak savanna. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Prunus virginiana	0	0	0	4	0.1250	4	12-24"	0	-
Salix interior	4	9	12	12	0.3750	12	8-12"	0	-
Spiraea alba	0	2	6	16	0.5000	16	6-12"	0	-

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

Stand 16, Aspen-oak woods. Density of reproduction (trees 1" or less DBH) and shrubs by plot size and per m^2; density and height range by two age classes.

	Number					Number per $8m^2$ plot and range of height by age classes			
	Per plot				Per m^2*				
	Plot size, m^2					4 years or less		Over 4 years	
Species	1	2	4	8		No.	Ht.	No.	Ht.
Amelanchier alnifolia	0	3	6	9	0.2812	6	6-72"	3	6'
Cornus alternifolia	1	4	5	6	0.1875	6	12-36"	0	-
Cornus racemosa	3	5	9	25	0.7812	19	12-60"	6	5-6'
Cornus stolonifera	6	8	18	25	0.7812	20	12-72"	5	4-8'
Corylus americana	26	55	88	152	4.7500	112	3-60"	40	3-7'
Populus balsamifera	0	1	2	3	0.0938	3	48-60"	0	-
Prunus virginiana	7	7	11	12	0.3750	10	6-48"	2	6-7'
Quercus macrocarpa	1	1	1	3	0.0938	3	6-24"	0	-
Rosa blanda	3	6	12	21	0.6562	19	12-48"	2	4-5'
Salix sp.	0	0	0	2	0.0625	0	-	2	3-7'
Symphoricarpos occidentalis	3	4	6	9	0.2812	8	4-60"	1	4'

* Based on $8m^2$ plot size.

Basis: 4 plots of each size given.

5.22 Herb and Vine Data

Stand 2, Bur oak woods. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Amphicarpa bracteata	25	25	25	25
Aster sp.	75	75	75	75
Carex brevior	50	50	50	50
Celastrus scandens	0	0	0	25
Circaea quadrisulcata	50	50	50	50
Galium boreale	25	25	25	25
Galium triflorum	50	50	50	50
Hydrophyllum virginianum	100	100	100	100
Lathyrus venosus	25	25	25	25
Mentha arvensis	25	25	25	25
Osmorhiza claytoni	25	25	25	25
Parthenocissus quinquefolia	0	50	50	50
Poa pratensis	75	75	75	100
Polygonatum canaliculatum	25	25	25	50
Potentilla sp.	25	25	25	25
Smilacina stellata	50	50	50	50
Taraxacum officinale	0	25	25	25
Thalictrum dioicum	25	25	25	25
Viola sp.	75	75	75	75
Vitis riparia	0	50	50	75

Basis: 4 plots of each size given.

Stand 5, Bur oak woods. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Anemone canadensis	50	75	75	75
Bidens frondosa	0	0	25	50
Galium boreale	25	25	25	25
Galium triflorum	50	75	75	100
Geum sp.	0	0	0	50
Hackelia virginiana	0	0	0	50
Hydrophyllum virginianum	0	0	25	25
Leonurus cardiaca	0	0	0	25
Melilotus officinalis	25	25	25	25
Parthenocissus quinquefolia	0	0	25	25
Poa pratensis	50	75	75	75
Polygonatum canaliculatum	0	25	25	25
Viola sp.	0	0	25	25

Basis: 4 plots of each size given.

Stand 6, Bur oak woods. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Amphicarpa bracteata	0	25	25	25
Arctium minus	25	25	25	25
Arisaema atrorubens	0	0	0	25
Laportea canadensis	50	50	50	50
Parthenocissus quinquefolia	75	75	75	100
Phryma leptostachya	0	25	25	25
Poa pratensis	25	25	25	50
Smilacina stellata	0	25	25	25
Thalictrum dioicum	0	0	25	25
Vicia americana	25	25	25	25
Viola sp.	0	0	0	25

Basis: 4 plots of each size given.

Stand 7, Bur oak savanna. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Ambrosia psilostachya	75	75	75	75
Amorpha canescens	50	50	75	75
Andropogon gerardi	25	25	25	50
Andropogon scoparius	50	75	75	100
Anemone patens	0	0	25	25
Aristida tuberculosa	25	25	25	25
Artemisia ludoviciana	0	0	0	25
Aster ericoides	0	0	25	25
Calamovilfa longifolia	50	100	100	100
Carex sp.	100	100	100	100
Heuchera richardsoni	0	0	25	25
Koeleria cristata	0	25	25	25
Liatris aspera	0	0	0	25
Lithospermum canescens	0	25	25	25
Lithospermum caroliniense	25	25	75	75
Panicum capillare	50	50	50	100
Panicum virgatum	0	0	0	25
Poa pratensis	100	100	100	100
Solidago nemoralis	25	25	25	50
Stipa comata	0	0	25	25
Tragopogon dubius	25	25	25	25

Basis: 4 plots of each size given.

Stand 10, Bur oak woods. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Agastache foeniculum	0	0	0	25
Anemone riparia	0	25	25	25
Bromus inermis	25	50	50	50
Carex pensylvanica	100	100	100	100
Elymus canadensis	0	75	75	75
Fragaria virginiana	25	50	50	50
Galium boreale	50	75	75	75
Maianthemum canadense	50	50	50	75
Parthenocissus quinquefolia	0	0	0	25
Poa pratensis	75	75	75	75
Polygonatum canaliculatum	25	25	25	25
Prenanthes alba	25	25	25	25
Smilax herbacea	0	25	50	50
Smilacina stellata	25	25	25	25
Thalictrum dioicum	50	50	50	50
Vicia americana	0	0	0	25
Viola sp.	0	0	25	25

Basis: 4 plots of each size given.

Stand 11, Prairie. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Allium stellatum	100	100	100	100
Amorpha canescens	75	75	75	75
Andropogon gerardi	100	100	100	100
Andropogon scoparius	75	75	75	75
Anemone cylindrica	50	100	100	100
Antennaria neglecta var. neglecta	25	25	25	25
Apocynum androsaemifolium	25	25	50	50
Aster puniceus	75	75	75	100
Astragalus crassicarpus	100	100	100	100
Bouteloua curtipendula	0	25	25	25
Campanula rotundifolia	25	50	50	50
Carex sp.	75	100	100	100
Elymus canadensis	25	50	75	100
Erigeron strigosus	0	25	25	25
Fragaria virginiana	50	50	50	50
Galium boreale	75	75	75	100
Heliopsis helianthoides	25	25	25	25
Koeleria cristata	50	100	100	100
Lathyrus venosus	0	0	0	25
Liatrus aspera	50	100	100	100
Lithospermum canescens	50	50	50	50
Melilotus alba	25	25	25	25
Monarda fistulosa	25	25	25	25
Panicum liebergii	100	100	100	100
Penstemon gracilis	50	50	50	50
Petalostemum candidum	50	75	75	75
Petalostemum purpureum	75	75	100	100
Phlox pilosa	25	25	25	25
Psoralea argophylla	50	50	50	50
Psoralea cuspidata	25	25	25	25
Ranunculus repens	25	25	50	50
Smilacina stellata	0	50	50	50
Solidago canadensis	0	0	25	25
Solidago rigida	50	50	50	50
Stipa spartea	100	100	100	100
Thalictrum dasycarpum	50	75	75	75
Veronicastrum virginicum	25	25	50	50
Zizia aptera	25	50	50	50
Zizia aurea	0	0	75	75
Zygadenus glaucus	25	25	25	25

Basis: 4 plots of each size given.

Stand 12, Bur oak woods. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Amphicarpa bracteata	50	50	50	75
Apocynum androsaemifolium	0	0	25	25
Aralia nudicaulis	50	50	50	50
Carex sp.	25	25	50	75
Desmodium glutinosum	50	75	75	100
Elymus canadensis	0	0	50	50
Fragaria virginiana	0	0	0	25
Heracleum lanatum	0	0	0	25
Parthenocissus quinquefolia	25	25	25	75
Phryma leptostachya	0	0	25	25
Sanguinaria canadensis	0	50	50	75
Smilacina racemosa	0	0	0	50
Smilacina stellata	0	0	0	25
Thalictrum dioicum	50	75	75	75
Trillium grandiflorum	0	25	25	25
Uvularia grandiflora	100	100	100	100
Vicia americana	25	25	25	25
Viola sp.	25	50	50	50
Zizia aurea	25	75	75	75

Basis: 4 plots of each size given.

Stand 14, Prairie. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Agropyron smithii	25	50	50	75
Agrostis stolonifera	100	100	100	100
Andropogon gerardi	100	100	100	100
Andropogon scoparius	75	75	75	75
Apocynum sibiricum	0	0	25	25
Asclepias ovalifolia	0	0	25	25
Aster ericoides	0	0	25	25
Aster ptarmicoides	0	0	0	25
Calamogrostis canadensis	100	100	100	100
Carex interior	75	100	100	100
Cirsium flodmanii	0	0	0	50
Equisetum kansanum	0	0	0	25
Liatris ligulistylis	25	25	75	100
Koeleria cristata	25	50	50	75
Penstemon gracilis	0	0	25	25
Petalostemum purpureum	0	25	75	75
Rudbeckia hirta	25	50	75	75
Solidago missouriensis	25	50	100	100
Taraxacum officinale	0	25	25	25
Thalictrum dasycarpum	25	25	50	50
Zizia aptera	0	25	25	50
Zizia aurea	100	100	100	100

Basis: 4 plots of each size given.

Stand 15, Bur oak savanna. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 1	2	4	8
Ambrosia psilostachya	25	25	50	50
Amorpha canescens	75	75	75	75
Andropogon gerardi	0	25	50	50
Andropogon scoparius	25	25	25	50
Anemone cylindrica	25	25	25	25
Artemisia ludoviciana	50	50	50	50
Aster sp.	25	25	25	25
Calamovilfa longifolia	50	50	50	50
Carex siccata	0	0	25	25
Koeleria cristata	25	25	25	50
Liatris aspera	25	25	25	25
Poa pratensis	100	100	100	100
Solidago missouriensis	50	50	75	75
Sorgastrum nutans	25	25	25	25
Stipa spartea	25	25	25	25

Basis: 4 plots of each size given.

Stand 16, Aspen-oak woods. Frequency (%) of herbs and vines by plot sizes.

Species	Plot size, m^2 .1	2	4	8
Aster macrophyllus	50	50	50	50
Bromus inermis	25	25	25	25
Elymus canadensis	75	75	75	75
Fragaria virginiana	50	50	75	75
Ipomea purpurea	25	25	25	50
Maianthemum canadense	75	75	100	100
Sanicula marilandica	50	100	100	100
Smilacina stellata	25	25	25	50
Solidago rigida	50	75	100	100
Thalictrum dioicum	25	75	75	75
Veronicastrum virginicum	0	0	0	25
Zizia aurea	75	75	75	75

Basis: 4 plots of each size given.

5.3 Soils Data

5.31 Soil Descriptions

Stand 2

General Site Characteristics:

Location - Jackson County, Minnesota, 7 mi. N and 4 mi. W of Jackson, Kilen Woods State Park; W½ NE¼ Sec. 17 and N¼ SW¼ Sec. 16, T 103 N, R 35 W, 5th P.M.

Elevation - About 1425 feet.

Topography - Mostly level land intersected by large draw with perennial stream; N aspect, 0-5% slope, upland above draw.

Drainage - Well drained; moderate permeability.

Parent material - Calcareous loam till of Wisconsin age.

Vegetation - Bur oak woods (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None.

Climate - Mean annual temperature, 46°F; mean annual precipitation, 26 inches.

Soil family - Typic Hapludolls, fine-loamy, mixed, mesic; resembling the Clarion series.

Profile Description:

A soil pit was not dug at this stand as it was within a small state park. See Section 5.32 for a chemical and physical description of the soil.

Stand 5

General Site Characteristics:

Location - Lyon County, Minnesota, 14 mi. S of Marshall; NW¼ SW¼ Sec. 11, T 109 N, R 40 W, 5th P.M.

Elevation - About 1450 feet.

Topography - Rolling with draws and small seasonal streams; uplands above Cottonwood River; S 60° E aspect, 5-10% slope, upper slope.

Drainage - Well drained; moderate permeability.

Parent material - Calcareous till of late Wisconsin age.

Vegetation - Bur oak woods (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None.

Climate - Mean annual temperature, 45°F; mean annual precipitation, 25 inches.

Soil family - Udic Argiborolls, fine-loamy, mixed; similar to the Forman series.

Profile Description:

O1 1 - 0.5 inches. Litter; boundary abrupt-smooth.

O2 0.5 - 1 inches. Decomposed litter; roots plentiful; boundary abrupt-smooth.

A1 0 - 7 inches. Very dark brown (10 YR 2/2, moist) clay loam (32½% sand, 35% silt, 32½% clay); dark gray (10 YR 4/1.5) when dry; weak, medium, crumb structure; pores many; roots

plentiful; pH slightly acid (6.3); bulk density 1.14 g/cc; 7.28% organic matter; 78% base saturation; boundary abrupt-wavy.

A3 7 - 10 inches. Dark brown (10 YR 3/3, moist) clay loam (36½% sand, 26½% silt, 37% clay); dark brown (10 YR 3/3) when dry; weak, medium, crumb structure; pores many; roots few; pH strongly acid (5.5); 5.17% organic matter; 76.1% base saturation; boundary abrupt-wavy.

B1 10 - 12 inches. Dark brown (10 YR 3/3, moist) clay loam; dark brown (10 YR 3/3) when dry; moderate, medium, crumb structure; pores common; roots few; boundary clear-wavy.

B2 12 - 18 inches. Dark brown (10 YR 3/3, moist) clay loam (38½% sand, 23½% silt, 38% clay); yellowish brown (10 YR 5/4) when dry; strong, medium, subangular blocky structure; pores few; roots few; pH medium acid (5.8); 4.48% organic matter; 77.3% base saturation; boundary clear-wavy.

B3 18 - 20 inches. Dark brown (10 YR 4/3, moist) clay loam; pale brown (10 YR 6/3) when dry; strong, medium, subangular blocky structure; pores few; roots very few; boundary clear-wavy.

C1 20 - 27 inches. Yellowish brown (10 YR 5/5, moist) sandy clay loam (45½% sand, 23½% silt, 31% clay); very pale brown (10 YR 7/3) when dry; pores few; roots very few; pH neutral (7.3); 100% base saturation; boundary gradual-wavy.

C2 27 + inches. Yellowish brown (10 YR 5/6, moist) clay loam (31½% sand, 34½% silt, 34% clay); very pale brown (10 YR 7/3.5) when dry; pores few; roots very few; pH mildly alkaline (7.8); 100% base saturation.

Additional information on nutrient status and physical properties may be found in Section 5.32 . There is a gradation of organic matter on the ped faces from B1-C which is very pronounced. Rocks 1-2 inches in diameter are present in increasing amounts from B1-C.

Stand 6

General Site Characteristics:

Location - Pope County, Minnesota, 3 mi. NW of Glenwood; NE¼ SE¼ Sec. 28, T 126 N, R 38 W, 5th P.M.

Elevation - About 1450 feet.

Topography - Top of rolling hills, above marshland and lakes; N 70° E aspect, 0-5% slope.

Drainage - Well drained; permeability moderate.

Parent material - Calcareous till of late Wisconsin age.

Vegetation - Bur oak woods (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None.

Climate - Mean annual temperature, 44°F; mean annual precipitation, 24 inches.

Soil family - Mollic Eutroboralfs, fine-loamy, mixed; resembling the Waukon series.

Profile Description:

O1 1.5 - 0.5 inches. Leaf litter; boundary abrupt-smooth.

O2 0.5 - 0 inches. Decomposed litter; boundary abrupt-smooth.

A1 0 - 7 inches. Black (10 YR 2/1, moist) loam (36% sand, 39½% silt, 24½% clay); very dark gray (10 YR 3/1) when dry; moderate, fine, crumb structure; pores common; roots plentiful; pH slightly acid (6.2); bulk density 0.83 g/cc; 11.01% organic matter; 74.9% base saturation; boundary abrupt-wavy.

A3 7 - 8.5 inches. Very dark brown (10 YR 2/2, moist) clay loam (43% sand, 23½% silt, 33½% clay); very dark gray (10 YR 3/1) when dry; moderate, fine, crumb structure; pores common; roots plentiful; pH slightly acid (6.3); 5.91% organic matter; 76.4% base saturation; boundary abrupt-wavy.

B1 8.5 - 9.5 inches. Dark brown (10 YR 3/3, moist) clay loam; dark gray (10 YR 4/1) when dry; moderate, fine, angular blocky structure; pores common; roots few; boundary abrupt-wavy.

B2 9.5 - 18 inches. Dark brown (10 YR 4/3, moist) sandy clay loam (47% sand, 20% silt, 33% clay); dark gray brown (10 YR 4/2) when dry; moderate, fine, angular blocky structure; pores few; roots few; pH neutral (6.6); bulk density 1.21 g/cc; 3.63% organic matter; 81.5% base saturation; few limestone rocks 1-4 inches diameter; abrupt-irregular.

C 18 + inches. Dark yellowish brown (10 YR 4/4, moist) sandy clay loam (48% sand, 20½% silt, 31½% clay); yellowish brown (10 YR 5/4) when dry; moderate, fine, angular blocky structure; pH neutral (7.3); 98.8% base saturation; numerous limestone rocks 1-4 inches diameter.

Additional information on nutrient status and physical properties may be found in Section 5.32 . At the 36 inch depth, the texture was clay (23% sand, 28% silt 49% clay), pH mildly alkaline (7.6), 99.0% base saturation.

Stand 7

General Site Characteristics:

Location - Anoka County, Minnesota, East Bethel, Allison Savanna Nature Conservancy Area; NE$\frac{1}{2}$ NE$\frac{1}{4}$ Sec. 2, T 133 N, R 23 W, 5th P.M.

Elevation - About 910 feet.

Topography - Rolling sand dunes; S aspect, 0-5% slope, upper slope.

Drainage - Excessively drained; rapid permeability.

Parent material - Aeolian fine sand.

Vegetation - Bur oak savanna (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None or some dune blowouts.

Climate - Mean annual temperature, 43°F; mean annual precipitation, 30 inches.

Soil family - Typic Udipsamments, mixed, frigid; resembling the Sartell series.

Profile Description:

No soil pit was dug in this stand, as it is a small, intensively used area. See Section 5.32 for a chemical and physical description of the soil.

Stand 10

General Site Characteristics:

Location - Hubbard County, Minnesota, 3/4 mi. S of Hubbard; W½ SE¼ SW¼ Sec. 29, T 139 N, R 34 W, 5th P.M.

Elevation - About 1410 feet.

Topography - Level land above slightly rolling topography.

Drainage - Well drained; rapid permeability.

Parent material - Coarse sandy outwash.

Vegetation - Bur oak woods (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None.

Climate - Mean annual temperature, 40°F; mean annual precipitation, 26 inches.

Soil family - Udic Haploborolls, sandy, mixed; resembles the Hubbard series.

Profile Description;

01 3.5 - 2 inches. Leaf litter; boundary abrupt-wavy.

02 2 - 0 inches. Decomposed litter; roots plentiful; boundary abrupt-smooth.

A1 0 - 3 inches. Black (7.5 YR 2/0, moist) sand (82% sand, 10% silt, 8% clay); black (10 YR 2/1) when dry; single grain to weak, coarse, crumb structure; loose (dry), very friable (moist), nonsticky (wet) consistence; pores few; roots plentiful; pH slightly acid (6.3); 4.55% organic matter; 63.7% base saturation;

Boundary abrupt-wavy.

B1 3 - 7 inches. Very dark gray brown (10 YR 3/2, moist) sand; dark brown (10 YR 3.5/3) when dry; single grain to weak, coarse, crumb structure; loose (dry), very friable (moist), nonsticky (wet) consistence; pores few; roots plentiful; bulk density 1.27 g/cc; boundary clear-wavy.

B2 7 - 11 inches. Very dark gray brown (10 YR 3/2, moist) sand (84½% sand, 11½% silt, 4% clay); dark brown (10 YR 4/3) when dry; single grain to weak, coarse, crumb structure; loose (dry), very friable (moist), slightly sticky (wet) consistence; pores few; roots few; pH medium acid (6.0); 2.44% organic matter; 55.5% base saturation; boundary clear-irregular.

C 11 + inches. Dark yellowish brown (10 YR 4.5/4, moist) loamy sand (77% sand, 11% silt, 12% clay); yellowish brown (10 YR 5.5/8) when dry; single grain structure; loose (dry); very friable (moist), slightly sticky (wet) consistence; roots few; pH medium acid (5.8); bulk density 1.62 g/cc; 2.45% organic matter; 56% base saturation.

Additional information on nutrient status and physical properties may be found in Section 5.32 . At the 24 inch depth, the texture was a loamy sand (78% sand, 10% silt, 12% clay), with a pH medium acid (5.8), 1.87% organic matter, and 50.4% base saturation; at the 36 inch depth, the texture was a sand (91% sand, 3% silt, 6% clay), with a pH medium acid (6.0), 0.87% organic matter, and 42.7% base saturation.

Stand 11

General Site Characteristics:

Location - Mahnomen County, Minnesota, 8½ mi. E of Mahnomen and ¼ mi. S; NW¼ NW¼ Sec. 5, T 144 N, R 40 W, 5th P.M.

Elevation - About 1320 feet.

Topography - Middle slope above small lake, E 20° S aspect, 6% slope.

Drainage - Moderately well drained; moderate permeability.

Parent material - Calcareous till of late Wisconsin age.

Vegetation - Prairie (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None.

Climate - Mean annual temperature, 40°F; mean annual precipitation, 24 inches.

Soil family - Aquic Argiborolls, fine, montmorillonitic; resembles the Gonvick series.

Profile Description:

O1 0.5 - 0.1 inches. Litter; boundary very abrupt-smooth.

O2 0.1 - 0 inches. Decomposed litter, boundary very abrupt-smooth.

A1 0 - 12 inches. Black (7.5 YR 2/0, moist) clay loam (37% sand, 35% silt, 28% clay); black (10 YR 2/1) when dry; moderate, medium, crumb structure; weakly coherent (dry); friable (moist), slightly sticky (wet) consistence; pores common; roots plentiful;

pH slightly acid (6.5); bulk density 0.93 g/cc; 11.22% organic matter; 82.3% base saturation; boundary abrupt-wavy.

B1 12 - 16 inches. Very dark gray (10 YR 3/1.5, moist) clay (18% sand, 34½% silt, 47½% clay); dark gray (10 YR 4.5/1) when dry; moderate, medium crumb structure; slightly hard (dry), friable (moist), slightly sticky (wet) consistence; pH strongly acid (5.5); 7.86% organic matter; 100% base saturation; boundary abrupt-wavy.

B2 16 - 26 inches. Dark yellowish brown (10 YR 4.5/4, moist) silty clay loam (19% sand, 31% silt, 50% clay); light gray (10 YR 7/1.5) when dry; strong, coarse, subangular blocky structure; slightly hard (dry), firm (moist), sticky (wet) consistence; pH strongly acid (5.5); bulk density 1.34 g/cc; 100% base saturation; boundary abrupt-wavy.

B3 26 + inches. Yellowish brown (10 YR 5.2/4, moist) clay loam (24% sand, 33½% silt, 42½% clay); light gray (10 YR 7/2) when dry; moderate to strong; coarse, subangular blocky structure; slightly hard (dry), firm (moist), sticky (wet) consistence; pH strongly acid (5.3); 100% base saturation.

Additional information on nutrient status and physical properties may be found in Section 5.32.

Stand 12

General Site Characteristics:

Location - Mahnomen County, Minnesota, 8½ mi. E of Mahnomen and ¼ mi. S; SE¼ SE¼ NE¼ and NE¼ NE¼ SE¼ Sec. 6, T 144 N, R 40 W, 5th P.M.

Elevation - About 1370 feet.

Topography - Hill above prairie and marsh land, E aspect, near top of hill, 3-20% slope.

Drainage - Well drained; moderate permeability.

Parent material - Calcareous till of late Wisconsin age.

Vegetation - Bur oak woods (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None.

Climate - Mean annual temperature, 40°F; mean annual precipitation, 24 inches.

Soil family - Udic Argiborolls, fine, montmorillonitic.

Profile Description:

O1 3 - 1 inches. Litter; boundary abrupt-smooth.

O2 1 - 0 inches. Decomposed litter; roots plentiful; boundary abrupt-smooth.

A1 0 - 14 inches. Very dark brown (10 YR 2.5/2, moist) loam (39% sand, 34% silt, 27% clay); very dark gray (10 YR 3.5/1) when dry; weak, fine, crumb structure; friable (moist), slightly sticky (wet) consistence; pores common; roots plentiful; pH mildly

alkaline (7.4); bulk density 1.12 g/cc; 10.61% organic matter; 100% base saturation; boundary clear-wavy.

A3 14 - 23 inches. Very dark gray (10 YR 3/1, moist) clay (27% sand, 29% silt, 44% clay); brown (10 YR 5/3) when dry; moderate, medium, crumb texture; friable (moist), slightly sticky (wet) consistence; pores common; roots plentiful; pH neutral (7.1); bulk density 1.21 g/cc; 4.61% organic matter; 100% base saturation; boundary gradual-wavy.

B2 23 - 37 inches. Very dark gray brown (10 YR 3/2.5, moist) clay (26.5% sand, 33.5% silt, 40% clay); light gray (10 YR 7/2) when dry; moderate, medium, crumb structure; firm (moist), sticky (wet) consistence; pores few; roots few; pH mildly alkaline (7.6); 100% base saturation; boundary clear-wavy.

B3 37 + inches. Dark brown (10 YR 4/3, moist) clay (19% sand, 38% silt, 43% clay); yellowish brown (10 YR 5/4) when dry; moderate, coarse, subangular blocky structure; firm (moist), sticky (wet) consistence; pH mildly alkaline (7.7); 100% base saturation; some calcareous rocks present.

Additional information on nutrient status and physical properties may be found in Section 5.32.

Stand 13

General Site Characteristics:

Location - Norman County, Minnesota, 4 mi. E of Syre and 1 1/8 mi. N; NW¼ SW¼ SW¼ Sec. 17, T 143 N, R 43 W, 5th P.M.

Elevation - About 1310 feet.

Topography - Level land on top of moraine ridge.

Drainage - Well drained; moderate permeability.

Parent material - Calcareous loamy till of late Wisconsin age.

Vegetation - Bur oak woods (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None to very little.

Climate - Mean annual temperature, 40°F; mean annual precipitation, 23 inches.

Soil family - Udic Haploborolls, fine-loamy, mixed; resembles the Barnes series.

Profile Description:

01 1 - 0.25 inches. Litter; boundary abrupt-smooth.

02 0.25 - 0 inches. Decomposed litter; boundary abrupt-smooth.

A1 0 - 7.5 inches. Black (10 YR 2/1, moist) sandy loam (52½% sand, 34½% silt, 13% clay); very dark gray (10 YR 3/1) when dry; moderate, medium, crumb structure; weakly coherent (dry), friable (moist), slightly sticky (wet) consistence; pores

common; roots plentiful; pH neutral (6.7); bulk density 1.11 g/cc; 9.50% organic matter; 77.2% base saturation; boundary clear-smooth.

B1 7.5 - 11 inches. Very dark brown (10 YR 2/2, moist) sandy loam (57% sand, 30% silt, 13 % clay); very dark gray brown (10 YR 3.5/2.5) when dry; moderate, medium, crumb structure, weakly coherent (dry), friable (moist), slightly sticky (wet) consistence; pores common; roots plentiful; pH slightly acid (6.2); 6.31% organic matter; 68.7% base saturation; boundary clear-wavy.

B2 11 - 22 inches. Dark brown (10 YR 3.5/3, moist) sandy loam (63% sand, 18% silt, 19% clay); dark yellowish brown (10 YR 4/4) when dry; moderate coarse, crumb to subangular blocky structure; slightly hard (dry), friable (moist), sticky (wet) consistence; pores common; roots plentiful; pH slightly acid (6.1); bulk density 1.32 g/cc; 2.31% organic matter; 68.9% base saturation; boundary clear-wavy.

B3 22 + inches. Brown (10 YR 5.5/3, moist) sandy clay loam (61% sand, 18% silt, 21% clay); light brownish gray (10 YR 6.5/2.5) when dry; moderate, medium, crumb structure; slightly hard (dry), friable (moist), sticky (wet) consistence; pores few; roots few; pH slightly acid (6.1); 70.9% base saturation.

Additional information on nutrient status and physical properties may be found in Section 5.32 . At the 36 inch depth, the texture was loam (45½% sand, 27½% silt, 27% clay) with a pH mildly alkaline (7.6) and a 100% base saturation.

Stand 14

General Site Characteristics:

Location - Clay County, Minnesota, 3½ mi. E of Glyndon and 1½ mi. S; SE¼ NE¼ Sec. 16, T 139 N, R 46 W, 5th P.M.

Elevation - About 940 feet.

Topography - Level land.

Drainage - Poorly to somewhat poorly drained; permeability moderate.

Parent material - Calcareous till of late Wisconsin age and lacustrine sediments.

Vegetation - Prairie (description found in Sections 2.221, 2.322, 5.1, and 5.2).

Erosion - None.

Climate - Mean annual temperture, 42°F; mean annual precipitation, 22 inches.

Soil family - Typic Haplaquolls, coarse-loamy, mixed, calcareous, frigid.

Profile Description:

O1 1 - 0.5 inches. Litter; boundary very abrupt-smooth.

O2 0.5 - 0 inches. Decomposed litter; boundary abrupt-smooth.

A1 0 - 8.5 inches. Black (2.5 Y 2/0, moist) sandy loam (63½% sand, 22% silt, 14½% clay); very dark gray (2.5 Y 3/0) when dry; single grain structure; pores common; roots abundant; pH moderately alkaline (7.9); bulk density 1.12 g/cc; 9.58%

organic matter; 100% base saturation; boundary abrupt-wavy.

A3 8.5 - 11 inches. Black (2.5 Y 2.5/0, moist) sandy loam (64% sand, 17½% silt, 18½% caly); gray (2.5 Y 5/0) when dry; single grain structure; pores common; roots plentiful; pH moderately alkaline (7.9); 6.11% organic matter; 100% base saturation; boundary clear-wavy.

B1 11 - 17 inches. Dark gray (10 YR 4/1, moist) sandy loam (69% sand, 12% silt, 19% clay); light gray (2.5 Y 6.5/0) when dry; single grain structure; pores few; roots plentiful; pH moderately alkaline (8.0); 3.79% organic matter; 100% base saturation; boundary clear-wavy.

B2 17 - 32.5 inches. Dark gray (10 YR 4/1, moist) loamy sand (77½% sand, 8½% silt, 14% clay); gray (2.5 Y 6/0) when dry; single grain structure; pores common; roots few; pH moderately alkaline (8.1); 2.16% organic matter; 100% base saturation; boundary abrupt-wavy.

C 32.5 + inches. Dark brown (10 YR 4/3, moist) sand (89% sand, 3½% silt, 7½% clay); light brownish gray (10 YR 6/2) when dry; single grain structure; pores few; roots few; pH moderately alkaline (8.2); 0.63% organic matter; 100% base saturation.

Additional information on nutrient status and physical properties may be found in Section 5.32. Boulders are scattered over the surface and throughout the profile. Following heavy rains water table is at 2-3 feet below surface.

Stand 15

General Site Characteristics:

Location - Polk County, Minnesota, 1 mi. S of Fertile and ½ mi. W, Agassiz Dunes Nature Conservancy Area; W½ NE¼ Sec. 32, T 147 N, R 44 W, 5th P.M.

Elevation - About 1120 feet.

Topography - Sand dunes with all aspects, level to 40% slope, soil examined on level land.

Drainage - Excessively drained; rapid permeability.

Parent material - Aeolian fine sand.

Vegetation - Bur oak savanna (description found in Sections 2.221, 2.332, 5.1, and 5.2).

Erosion - None at soil pit to very severely eroded in dune blowouts.

Climate - Mean annual temperature, 40°F; mean annual precipitation, 22 inches.

Soil family - Typic Udipsamments, mixed, frigid.

Profile Description:

O1 0.5 - 0.25 inches. Litter; boundary very abrupt-smooth.

O2 0.25 - 0 inches. Decomposed litter; boundary abrupt-smooth.

A1 0 - 3.5 inches. Dark yellowish brown (10 YR 3/4, moist) sand (94% sand, 3% silt, 3% clay); dark gray brown (10 YR 4/2) when dry; single grain structure; roots abundant; pH slightly

acid (6.2); 1.59% organic matter; 51.4% base saturation; boundary abrupt-wavy.

A3 3.5 - 6 inches. Dark yellowish brown (10 YR 4/4, moist) sand (95% sand, 1½% silt, 3½% clay); brown (10 YR 5/3) when dry; single grain structure; roots abundant; pH slightly acid (6.2); bulk density 1.57 g/cc; 1.03% organic matter; 40.6% base saturation; boundary clear-wavy.

B1 6 - 8.5 inches. Dark yellowish brown (10 YR 4/4, moist) sand (94½% sand, 2% silt, 3½% clay); brown (10 YR 5/3) when dry; single grain structure; roots abundant; pH slightly acid (6.2); 0.61% organic matter; 40.2% base saturation; boundary clear-wavy.

B2 8.5 - 33.5 inches. Dark yellowish brown (10 YR 4/4, moist) sand (96% sand, ½% silt, 3½% clay); pale brown (10 YR 6/3) when dry; single grain structure; roots plentiful to few; pH slightly acid (6.4); bulk density 1.61 g/cc; 0.47% organic matter; 38.5% base saturation; boundary clear-wavy.

B3 33.5 + inches. Dark brown (10 YR 3/3, moist) sand (96% sand, 1% silt, 3% clay); brown (10 YR 5/3) when dry; single grain structure; roots very few; pH slightly acid (6.2); 0.35% organic matter; 40.2 % base saturation.

Additional information on nutrient status and physical properties may be found in Section 5.32.

Stand 16

General Site Characteristics:

Location - Marshall County, Minnesota, 3 mi. S of Karlstad; NE¼ SE¼ Sec. 5, T 158 N, R 45 W, 5th P.M.

Elevation - About 1050 feet.

Topography - Low, level.

Drainage - Imperfectly or somewhat poorly drained; moderately slow permeability.

Parent material - Calcareous loam glacial till with perhaps some lacustrine sediments.

Vegetation - Aspen woods (description found in Sections 2.221, 2.332, 5.1, and 5.2).

Erosion - None.

Climate - Mean annual temperature, 38°F; mean annual precipitation, 20 inches.

Soil family - Typic Haplaquolls, fine-loamy, mixed, frigid; resembles the Roliss series.

Profile Description:

O1 2 - 1 inches. Litter; boundary abrupt-smooth.

O2 1 - 0 inches. Decomposed litter; roots plentiful; boundary abrupt-smooth.

A1 0 - 5 inches. Very dark gray brown (10 YR 3/2, moist) sandy clay loam (57½% sand, 21½% silt, 21% clay); gray (10 YR 5/1) when dry; weak, fine, crumb structure; pores common; roots

plentiful; pH neutral (6.8); bulk density 1.26 g/cc; 3.48% organic matter; 80.8% base saturation; boundary abrupt-wavy.

A2 5 - 7 inches. Dark gray brown (10 YR 4/2, moist) sandy loam (64½% sand, 19½% silt, 16% clay); gray brown (10 YR 5/2) when dry; weak, medium, crumb structure; pores common; roots few; pH mildly alkaline (7.4); 2.66% organic matter; 100% base saturation; small rocks present; boundary abrupt-wavy.

B1 7 - 10 inches. Gray brown (10 YR 5/2, moist) clay loam (41½% sand, 30½% silt, 28% clay); light brownish gray (10 YR 6/2) when dry; weak, medium, crumb structure; pores common; roots plentiful; pH moderately alkaline (8.0); 100% base saturation; several large rocks present; boundary abrupt-wavy.

B2 10 + inches. Pale brown (10 YR 6/3, moist) clay loam (41½% sand, 30½% silt, 28% clay); light gray (10 YR 7.5/1) when dry; weak, medium crumb structure; pores few; roots few; pH moderately alkaline (8.1); bulk density 1.45 g/cc; 100% base saturation; many rocks present.

Additional information on nutrient status and physical properties may be found in Section 5.32 . The soil at 24 inches and below was too rocky to dig the soil pit deeper; the texture at 24 inches was clay loam (41½% sand, 30½% silt, and 28% clay).

5.32 Soil Physical and Chemical Properties

Stand 2, Bur oak woods. Soil physical and chemical properties.

Property	Soil Depth, inches 0-6	6-12	12-18	18-24	36
Bulk density (g/cc)	1.212	-	-	-	-
Texture					
% Sand	39	39	41	42	44.5
% Silt	37	31	29	26	24.5
% Clay	24	30	30	32	31
Moisture properties					
15 Bar moist. (%)	15.93	12.11	11.15	10.95	11.03
1/3 Bar moist. (%)	27.10	25.60	24.70	24.35	24.15
Avail. moist. (%)	11.17	13.49	13.55	13.40	13.12
Organic matter (%)	6.89	4.75	3.67	3.07	2.53
pH	6.2	5.6	5.6	5.5	5.3
Nitrogen (%)	0.219	0.132	0.091	0.063	0.042
Phosphorus (ppm)	9.5	4.1	2.8	2.0	3.9
Potassium (ppm)	81.3	43.5	46.3	44.5	45.7
Calcium (ppm)	3587	2633	2677	2193	2067
Magnesium (ppm)	445	429	457	481	493
Sodium (ppm)	15.5	21.3	24.1	26.4	30.1
Hydrogen (ppm)	80.9	87.1	74.7	68.6	63.8
Base saturation (%)	73.1	65.9	70.2	68.9	69.9
Bases (meq/100g)	21.87	16.90	17.37	15.23	14.64
CEC (meq/100g)	29.89	25.54	24.78	21.95	20.96

Basis: Average of 3 replications, except bulk density with 6 at 6 inches.

Stand 5, Bur oak woods. Soil physical and chemical properties.

Property	Soil Depth, inches 0–7	7–12	12–18	18–24	36
Bulk density (g/cc)	1.190	–	1.319	–	–
Texture					
% Sand	34	36	36.5	38.5	33
% Silt	34	30	27.5	29	32.5
% Clay	32	34	36	32.5	34.5
Moisture properties					
15 Bar moist. (%)	19.82	16.45	14.96	13.07	11.98
1/3 Bar moist. (%)	29.10	26.74	26.66	25.40	27.03
Avail. moist. (%)	9.28	10.29	11.70	12.33	19.05
Organic matter (%)	7.79	5.52	4.62	4.39	4.22
pH	6.4	6.1	6.3	7.2	7.7
Nitrogen (%)	0.237	0.141	0.105	0.081	0.048
Phosphorus (ppm)	10.2	6.1	4.9	2.6	3.4
Potassium (ppm)	87.7	61.5	53.8	47.9	36.1
Calcium (ppm)	4078	3268	3207	7687	9667
Magnesium (ppm)	558	476	447	409	388
Sodium (ppm)	31.1	32.1	29.9	28.0	33.0
Hydrogen (ppm)	82.3	74.0	63.0	0.0	0.0
Base saturation (%)	75.7	73.3	76.0	100.0	100.0
Bases (meq/100g)	25.34	20.55	19.98	42.05	51.76
CEC (meq/100g)	33.50	27.90	26.23	42.05	51.76

Basis: Average of 3 replications, except bulk density with 6 at 6 inches and 4 at 18 inches.

Stand 6, Bur oak woods. Soil physical and chemical properties.

Property	Soil Depth, inches 0–6	6–12	12–18	18–24	36
Bulk density (g/cc)	0.833	–	1.211	–	–
Texture					
% Sand	33.5	36	38.5	43.5	31
% Silt	44	29.5	25.5	24	29
% Clay	22.5	34.5	36	32.5	40
Moisture properties					
15 Bar moist. (%)	27.83	19.30	16.88	15.40	14.38
1/3 Bar moist. (%)	36.36	28.70	27.70	26.43	28.84
Avail. moist. (%)	8.53	9.40	10.82	11.03	14.46
Organic matter (%)	12.23	6.66	4.83	4.00	3.19
pH	6.0	5.9	6.0	6.9	7.5
Nitrogen (%)	0.416	0.196	0.121	0.093	0.063
Phosphorus (ppm)	26.9	11.2	6.8	3.0	1.6
Potassium (ppm)	103.7	74.6	65.3	62.7	45.7
Calcium (ppm)	5713	3533	2913	6933	9747
Magnesium (ppm)	745	676	696	644	716
Sodium (ppm)	16.9	24.1	29.5	33.0	32.5
Hydrogen (ppm)	147.4	95.3	76.1	27.4	4.1
Base saturation (%)	70.8	71.4	72.8	90.9	99.2
Bases (meq/100g)	38.71	25.97	20.59	40.27	54.88
CEC (meq/100g)	49.65	32.97	28.13	42.99	55.29

Basis: Average of 3 replications, except bulk density with 6 at 6 inches and 2 at 18 inches.

Stand 7, Bur oak savanna. Soil physical and chemical properties.

Property	Soil Depth, inches 0–6	6–12	12–18	18–24	36	48
Bulk density (g/cc)	1.496	–	1.566	–	–	–
Texture						
% Sand	92.5	92	93	94	94.5	94.5
% Silt	2.5	2	2	0.5	0.5	0.5
% Clay	5	6	5	5.5	5	5
Moisture properties						
15 Bar moist. (%)	2.72	2.56	2.00	1.86	1.41	1.27
1/3 Bar moist. (%)	4.01	3.50	2.82	2.63	1.90	1.83
Avail. moist. (%)	1.29	0.94	0.82	0.77	0.49	0.56
Organic matter (%)	1.63	1.42	0.99	0.92	0.59	0.47
pH	5.2	5.3	5.5	5.5	5.6	5.9
Nitrogen (%)	0.057	0.043	0.028	0.024	0.008	0.004
Phosphorus (ppm)	14.1	11.5	13.6	13.1	10.0	7.3
Potassium (ppm)	5.9	5.4	3.5	3.5	3.1	3.6
Calcium (ppm)	161	144	116	109	143	183
Magnesium (ppm)	19.4	17.5	12.6	12.3	15.9	19.7
Sodium (ppm)	0.3	3.2	1.5	1.7	2.4	3.3
Hydrogen (ppm)	56.9	43.9	37.7	33.6	26.7	24.0
Base saturation (%)	14.8	18.3	16.7	17.2	25.1	34.7
Bases (meq/100g)	0.98	0.89	0.70	0.66	0.86	1.10
CEC (meq/100g)	6.63	5.25	4.44	3.99	3.51	3.48

Basis: Average of 3 replications, except bulk density with 6 at 6 inches and 2 at 18 inches.

Stand 10, Bur oak woods. Soil physical and chemical properties.

Property	Soil Depth, inches 0-6	6-12	12-18	18-24	36
Bulk density (g/cc)	1.371	-	1.618	-	-
Texture					
% Sand	82.5	84	80	80.5	91.5
% Silt	9	8.5	9	8.5	2.5
% Clay	8.5	7.5	11	11	6
Moisture properties					
15 Bar moist. (%)	7.34	4.34	4.26	3.75	1.82
1/3 Bar moist. (%)	9.60	7.17	7.91	7.18	2.74
Avail. moist. (%)	2.26	2.83	3.65	3.43	0.92
Organic matter (%)	3.70	2.43	2.08	1.72	0.90
pH	5.8	5.7	5.6	5.7	5.9
Nitrogen (%)	0.110	0.068	0.048	0.037	0.014
Phosphorus (ppm)	49.5	62.6	55.7	46.4	20.3
Potassium (ppm)	23.5	9.3	10.1	8.1	3.4
Calcium (ppm)	1377	978	1075	821	340
Magnesium (ppm)	138	125	100	84	34
Sodium (ppm)	9.5	6.2	5.3	7.4	2.6
Hydrogen (ppm)	65.1	52.8	59.6	50.1	29.5
Base saturation (%)	56.7	53.3	51.0	48.4	40.8
Bases (meq/100g)	8.12	5.97	6.25	4.85	2.00
CEC (meq/100g)	14.58	11.21	12.16	9.81	4.93

Basis: Average of 3 replications, except bulk density with 6 at 6 inches and 4 at 18 inches.

Stand 11, Prairie. Soil physical and chemical properties.

Property	Soil Depth, inches 0–6	6–12	12–18	18–24	36
Bulk density (g/cc)	0.993	-	1.335	-	-
Texture					
% Sand	38	33.5	25.5	29	24
% Silt	44	35.5	33	30	32
% Clay	18	31	41.5	41	44
Moisture properties					
15 Bar moist. (%)	25.70	18.42	13.79	11.80	13.13
1/3 Bar moist. (%)	36.42	31.35	28.55	25.77	24.67
Avail. moist. (%)	10.72	12.93	14.76	13.97	11.54
Organic matter (%)	12.50	8.58	7.52	6.21	5.99
pH	7.1	7.4	7.7	7.9	8.0
Nitrogen (%)	0.433	0.188	0.092	0.048	0.066
Phosphorus (ppm)	6.9	2.4	1.0	0.5	1.0
Potassium (ppm)	69.7	59.1	48.9	39.3	40.4
Calcium (ppm)	6813	7367	10027	9707	9787
Magnesium (ppm)	921	791	804	679	923
Sodium (ppm)	15.9	17.3	19.5	23.7	24.1
Hydrogen (ppm)	24.0	0.0	0.0	0.0	0.0
Base saturation (%)	94.1	100	100	100	100
Bases (meq/100g)	41.89	43.56	56.96	54.32	56.73
CEC (meq/100g)	44.27	43.56	56.96	54.32	56.73

Basis: Average of 3 replications, except bulk density with 8 at 6 inches and 4 at 18 inches.

Stand 12, Bur oak woods. Soil physical and chemical properties.

Property	Soil Depth, inches 0–6	6–12	12–18	18–24	36
Bulk density (g/cc)	1.024	-	1.209	-	-
Texture					
% Sand	41	36.5	31.5	25	26
% Silt	34	28.5	28.5	36	34.5
% Clay	25	35	40	39	39.5
Moisture properties					
15 Bar moist. (%)	16.40	12.28	14.48	14.33	13.86
1/3 Bar moist. (%)	26.41	23.78	27.93	37.42	26.62
Avail. moist. (%)	10.01	11.50	13.45	13.09	12.76
Organic matter (%)	8.11	5.37	4.81	4.23	4.18
pH	6.9	7.0	7.3	7.7	7.8
Nitrogen (%)	0.068	0.054	0.174	0.182	0.090
Phosphorus)ppm)	54.4	18.9	13.3	6.7	1.6
Potassium (ppm)	76.5	57.8	67.8	57.3	52.6
Calcium (ppm)	4675	6310	6795	8900	9195
Magnesium (ppm)	658	540	980	618	607
Sodium (ppm)	15.0	14.6	16.6	17.0	17.2
Hydrogen (ppm)	35.0	33.9	15.4	0.0	0.0
Base saturation (%)	90.5	88.5	95.4	100	100
Bases (meq/100g)	29.04	36.21	40.27	49.80	51.18
CEC (meq/100g)	32.52	39.57	41.80	49.80	51.18

Basis: Average of 3 replications, except bulk density with 6 at 6 inches and 3 at 18 inches.

Stand 13, Bur oak woods. Soil physical and chemical properties.

Property	Soil Depth, inches 0–6	6–12	12–18	18–24	36
Bulk density (g/cc)	1.052	–	1.621	–	–
Texture					
% Sand	52	59.5	63	57.5	50.5
% Silt	35	26	21	21.5	25.5
% Clay	13	14.5	16	21	24
Moisture properties					
15 Bar moist. (%)	18.91	10.70	6.51	7.37	6.45
1/3 Bar moist. (%)	26.59	18.24	13.57	15.16	16.44
Avail. moist. (%)	7.68	7.54	7.06	7.79	9.99
Organic matter (%)	9.24	4.97	2.58	3.07	2.86
pH	6.7	6.4	6.5	6.7	7.3
Nitrogen (%)	0.318	0.157	0.071	0.061	0.041
Phosphorus (ppm)	18.5	12.6	6.0	2.5	2.6
Potassium (ppm)	71.4	43.0	31.9	27.3	18.7
Calcium (ppm)	4220	2277	1670	3857	6233
Magnesium (ppm)	626	425	367	379	433
Sodium (ppm)	15.8	15.3	16.3	18.2	19.7
Hydrogen (ppm)	74.7	63.7	41.1	28.8	12.3
Base saturation (%)	78.1	70.7	73.4	81.0	90.9
Bases (meq/100g)	26.5	15.05	11.52	22.55	34.86
CEC (meq/100g)	33.91	21.38	15.60	25.41	36.08

Basis: Average of 3 replications, except bulk density with 6 at 6 inches and 3 at 18 inches.

Stand 14, Prairie. Soil physical and chemical properties.

Property	Soil Depth, inches 0–6	6–12	12–18	18–24	36
Bulk density (g/cc)	1.127	–	1.302	–	–
Texture					
% Sand	69	69.5	67.5	75.5	83
% Silt	20.5	13.5	13	10	9.5
% Clay	10.5	17	19.5	14.5	7.5
Moisture properties					
15 Bar moist. (%)	19.35	9.69	8.83	5.76	2.17
1/3 Bar moist. (%)	25.79	22.34	21.28	15.21	5.39
Avail. moist. (%)	6.44	12.65	12.45	9.45	3.22
Organic matter (%)	9.13	5.36	4.43	2.76	0.93
pH	7.8	8.0	8.0	8.0	8.1
Nitrogen (%)	0.368	0.174	0.127	0.076	0.030
Phosphorus (ppm)	1.1	1.6	1.4	1.4	0.75
Potassium (ppm)	12.5	6.9	7.8	8.1	6.7
Calcium (ppm)	9633	9513	9227	8753	6300
Magnesium (ppm)	928	568	420	323	177
Sodium (ppm)	16.7	17.4	18.1	16.6	23.3
Hydrogen (ppm)	0	0	0	0	0
Base saturation (%)	100	100	100	100	100
Bases (meq/100g)	55.90	51.33	49.69	46.51	33.08
CEC (meq/100g)	55.90	51.33	49.69	46.51	33.08

Basis: Average of 3 replications, except bulk density with 6 at 6 inches and 3 at 18 inches.

Stand 15, Bur oak savanna, prairie type. Soil physical and chemical properties.

Property	Soil Depth, inches 0–3	3–6	6–12	12–18	18–24	36	48	78*
Bulk density (g/cc)	–	1.558	–	1.615	–	–	–	–
Texture								
% Sand	93	95	95	96	96	96	96	95.5
% Silt	3	2	1.5	1	1	1	1	1
% Clay	4	3	3.5	3	3	3	3	3.5
Moisture properties								
15 Bar moist. (%)	3.59	2.37	1.78	1.33	1.17	1.21	1.09	0.96
1/3 Bar moist. (%)	4.21	2.73	2.05	1.62	1.53	1.48	1.45	1.53
Avail. moist. (%)	0.62	0.36	0.27	0.29	0.36	0.27	0.36	0.57
Organic matter (%)	1.60	0.96	0.71	0.49	0.43	0.39	0.38	0.30
pH	6.3	6.2	6.2	6.2	6.3	6.3	6.3	6.2
Nitrogen (%)	0.056	0.036	0.021	0.014	0.012	0.007	0.006	0.004
Phosphorus (ppm)	11.7	9.3	9.2	7.7	7.7	9.3	12.4	16.1
Potassium (ppm)	8.8	6.3	5.9	5.5	4.8	4.7	5.5	5.0
Calcium (ppm)	580	358	268	222	206	212	209	160
Magnesium (ppm)	79.0	48.7	39.6	36.1	31.6	29.2	27.3	29.6
Sodium (ppm)	0.2	0.9	0.4	0.8	0.0	4.0	5.8	0.2
Hydrogen (ppm)	24.7	20.1	15.6	11.9	7.4	12.3	7.8	20.6
Base saturation (%)	59.8	53.2	53.2	56.7	70.1	54.7	64.4	34.1
Bases (meq/100g)	3.57	2.21	1.69	1.42	1.30	1.33	1.31	1.06
CEC (meq/100g)	6.02	4.21	3.24	2.61	2.03	2.55	2.08	3.10

Basis: Average of 5 replications, except bulk density with 10 at 6 inches and 9 at 18 inches.

* 1 sample.

Stand 15, Bur oak savanna, juniper type. Soil physical and chemical properties.

Property	Soil Depth, inches 0–3	3–6	6–12	12–18	18–24	36	48
Bulk density (g/cc)	–	1.533	–	1.617	–	–	–
Texture							
% Sand	93	94	95	96	95.5	96	95.5
% Silt	3	2.5	1.5	1	1	1	1
% Clay	4	3.5	3.5	3	3.5	3	3.5
Moisture properties							
15 Bar moist. (%)	4.25	2.76	1.80	1.54	1.40	1.25	1.17
1/3 Bar moist. (%)	4.48	3.04	2.24	1.93	1.72	1.64	1.54
Avail. moist. (%)	0.23	0.28	0.44	0.39	0.32	0.39	0.37
Organic matter (%)	1.67	1.14	0.76	0.75	0.52	0.47	0.42
pH	6.1	5.8	5.8	5.7	5.7	5.9	5.9
Nitrogen (%)	0.055	0.040	0.022	0.017	0.012	0.010	0.007
Phosphorus (ppm)	10.6	10.9	10.3	9.7	9.8	12.5	14.4
Potassium (ppm)	10.6	5.8	4.36	4.0	3.7	3.9	4.2
Calcium (ppm)	554	323	241	206	196	195	191
Magnesium (ppm)	88.4	54.5	39.2	33.0	29.4	25.9	25.6
Sodium (ppm)	2.8	0.0	0.3	2.4	0.0	0.0	0.0
Hydrogen (ppm)	30.5	28.0	18.5	18.9	14.4	14.4	25.5
Base saturation (%)	54.6	44.4	48.3	44.7	49.1	49.6	37.9
Bases (meq/100g)	3.54	2.08	1.54	1.32	1.23	1.20	1.18
CEC (meq/100g)	6.56	4.85	3.38	3.20	2.66	2.63	3.70

Basis: Average of 5 replications, except bulk density with 11 at 6 inches and 9 at 18 inches.

Stand 15, Bur oak savanna, oak-prairie type. Soil physical and chemical properties.

Property	Soil Depth, inches 0–3	3–6	6–12	12–18	18–24	36	48
Bulk density (g/cc)	–	1.465	–	1.592	–	–	–
Texture							
% Sand	92.5	94	95	95.5	95.5	96	96
% Silt	3.5	2.5	1.5	1	1.5	1	1
% Clay	4	3.5	3.5	3.5	3	3	3
Moisture properties							
15 Bar moist. (%)	4.56	3.46	2.29	1.72	1.46	1.27	1.20
1/3 Bar moist. (%)	5.10	3.88	2.72	2.03	1.85	1.91	1.60
Avail. moist. (%)	0.54	0.42	0.43	0.31	0.39	0.64	0.40
Organic matter (%)	1.95	1.43	0.89	0.61	0.50	0.41	0.38
pH	5.8	5.9	5.8	5.8	5.7	5.8	6.0
Nitrogen (%)	0.064	0.047	0.028	0.016	0.011	0.008	0.005
Phosphorus (ppm)	21.8	22.0	20.4	20.1	21.2	24.8	18.0
Potassium (ppm)	10.5	7.1	8.4	6.4	6.0	6.0	6.2
Calcium (ppm)	619	511	302	212	184	171	169
Magnesium (ppm)	70.0	49.2	41.1	33.4	43.1	29.8	36.8
Sodium (ppm)	2.5	3.8	2.2	2.0	2.7	4.3	2.7
Hydrogen (ppm)	39.1	32.5	26.7	22.6	21.0	19.8	23.0
Base saturation (%)	48.7	46.1	40.9	37.9	38.0	38.1	38.1
Bases (meq/100g)	3.71	2.99	1.88	1.36	1.30	1.13	1.18
CEC (meq/100g)	7.58	6.22	4.53	3.60	3.38	3.09	3.46

Basis: Average of 5 replications, except bulk density with 10 at 6 inches and 10 at 18 inches.

Stand 15, Bur oak savanna, oak-juniper type. Soil physical and chemical properties.

Property	Soil Depth, inches 0–3	3–6	6–12	12–18	18–24	36	48*
Bulk density (g/cc)	–	1.515	–	1.637	–	–	–
Texture							
% Sand	92	94	95	96	96	95.5	96
% Silt	3.5	2.5	1.5	1	1	1	1
% Clay	4.5	3.5	3.5	3	3	3.5	3
Moisture properties							
15 Bar moist. (%)	5.29	2.97	2.10	1.58	1.52	1.52	1.44
1/3 Bar moist. (%)	6.05	3.47	2.46	1.92	1.82	2.04	1.94
Avail. moist. (%)	0.76	0.50	0.36	0.34	0.30	0.52	0.50
Organic matter (%)	2.27	1.23	0.80	0.56	0.46	0.46	0.43
pH	5.8	5.9	5.7	5.7	5.6	5.7	5.6
Nitrogen (%)	0.069	0.038	0.023	0.014	0.011	0.009	0.007
Phosphorus (ppm)	19.4	22.7	19.1	16.1	14.4	16.6	18.4
Potassium (ppm)	21.2	13.1	8.2	6.5	5.7	5.5	4.8
Calcium (ppm)	728	372	235	184	183	214	178
Magnesium (ppm)	95.0	60.4	41.9	30.2	27.2	34.0	31.7
Sodium (ppm)	0.1	0.2	0.5	0.0	0.0	0.7	0.4
Hydrogen (ppm)	32.9	31.28	23.8	18.5	17.7	18.5	16.0
Base saturation (%)	55.6	43.5	40.6	40.6	42.0	45.6	37.4
Bases (meq/100g)	4.48	2.39	1.54	1.18	1.15	1.37	1.17
CEC (meq/100g)	7.74	5.49	3.91	3.02	2.91	3.20	3.15

Basis: Average of 5 replications, except bulk density with 10 at 6 inches and 8 at 18 inches.

* 4 samples.

Stand 15, Bur oak savanna, aspen-oak type. Soil physical and chemical properties.

Property	Soil Depth, inches 0–3	3–6	6–12	12–18	18–24	36	48
Bulk density (g/cc)	–	1.298	–	1.554	–	–	–
Texture							
% Sand	85.5	91.5	94	94.5	93	94	94.5
% Silt	8.5	4.5	2.5	2	3	2	1.5
% Clay	6	4	3.5	3.5	4	4	4
Moisture properties							
15 Bar moist. (%)	12.58	5.30	2.93	2.12	1.68	1.48	1.56
1/3 Bar moist. (%)	14.79	6.68	3.64	2.53	2.34	2.33	2.41
Avail. moist. (%)	2.21	1.38	0.71	0.41	0.66	0.85	0.85
Organic matter (%)	6.13	2.72	1.21	0.76	0.50	0.41	0.42
pH	5.4	5.4	5.5	5.6	6.3	6.2	6.0
Nitrogen (%)	0.187	0.086	0.045	0.022	0.010	0.007	0.005
Phosphorus (ppm)	19.4	22.8	20.8	23.0	17.2	22.0	18.6
Potassium (ppm)	12.4	10.0	6.2	5.4	6.8	7.0	7.2
Calcium (ppm)	1264	518	281	230	255	222	219
Magnesium (ppm)	209.0	88.7	51.4	48.3	69.6	52.1	37.8
Sodium (ppm)	12.8	7.7	11.8	8.8	12.6	11.1	9.0
Hydrogen (ppm)	119.3	70.4	39.1	27.2	13.9	14.4	16.4
Base saturation (%)	41.9	36.4	33.5	35.0	54.5	55.3	48.9
Bases (meq/100g)	8.12	3.37	1.90	1.60	1.92	1.60	1.46
CEC (meq/100g)	19.96	10.36	5.77	4.30	3.30	3.03	3.10

Basis: Average of 4 replications, except bulk density with 8 at 6 inches and 6 at 18 inches.

Stand 16, Aspen-oak woods. Soil physical and chemical properties.

Property	Soil Depth, inches 0-4*	4-6*	0-6	6-12	12-18	18-24
Bulk density (g/cc)	-	-	1.309	-	1.450	-
Texture						
% Sand	57.5	64.5	55.5	44.5	39	38.5
% Silt	21.5	19.5	21	28.5	31	31.5
% Clay	21	16	23.5	27	30	30
Moisture properties						
15 Bar moist. (%)	11.00	8.09	11.44	8.44	8.35	7.32
1/3 Bar moist. (%)	19.41	13.56	19.26	18.94	19.29	17.52
Avail. moist. (%)	8.41	5.50	7.86	10.50	10.94	10.20
Organic matter (%)	3.48	2.66	3.46	4.30	4.85	4.11
pH	6.8	7.4	7.2	7.9	8.1	8.2
Nitrogen (%)	0.101	0.049	0.086	0.060	0.039	0.025
Phosphorus (ppm)	5.1	2.6	4.0	1.2	1.3	1.7
Potassium (ppm)	37.4	24.6	36.0	21.1	16.2	15.1
Calcium (ppm)	2760	3360	3295	8053	8467	8747
Magnesium (ppm)	710	938	905	779	756	903
Sodium (ppm)	11.6	17.2	13.1	12.7	15.9	15.3
Hydrogen (ppm)	47.3	0.0	11.8	0.0	0.0	0.0
Base saturation (%)	80.8	100	95.2	100	100	100
Bases (meq/100g)	19.78	24.65	24.06	46.78	48.66	51.26
CEC (meq/100g)	24.48	24.65	25.24	46.78	48.66	51.26

Basis: Average of 3 replications, except bulk density with 6 at 6 inches and 2 at 18 inches.

* 1 sample.

5.4 Plant Nutrient Concentration Data

Stand 2, Bur oak woods. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Fraxinus pennsylvanica	0.4224	1.6035	1.0809	0.2686	0	24.12
Parthenocissus quinquefolia	0.3636	1.7191	1.2634	0.3025	0	33.27
Poa pratensis	0.1864	1.9785	0.2428	0.1487	0	22.05
Prunus virginiana	0.3809	1.3818	3.3477	0.4238	0	55.63
Quercus macrocarpa	0.2037	1.0770	0.9460	0.2430	0	21.85
Ribes cynosbati	0.3714	3.0262	1.2061	0.2607	0	35.52
Symphoricarpos occidentalis	0.4190	2.2739	0.6131	0.3007	0	12.03
Tilia americana	0.2849	1.8678	1.4938	0.3682	0	31.38
Ulmus americana	0.2590	1.1875	1.4980	0.3302	0	31.38
Xanthoxylum americanum	0.4069	2.2044	1.3205	0.2488	0	28.68

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 2, Bur oak woods. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Fraxinus pennsylvanica	67.05	20.22	11.48	5.88	44.71	50.71
Parthenocissus quinquefolia	108.74	16.46	9.40	8.11	140.62	108.82
Poa pratensis	74.19	21.74	5.03	4.40	55.28	55.26
Prunus virginiana	82.29	13.17	6.61	7.66	402.54	91.44
Quercus macrocarpa	74.50	21.26	7.72	7.06	547.49	64.98
Ribes cynosbati	78.86	13.09	5.34	5.88	147.03	66.54
Symphoricarpos occidentalis	41.72	14.79	5.26	7.51	86.82	61.22
Tilia americana	76.52	19.38	9.08	7.81	128.31	79.17
Ulmus americana	118.92	17.00	6.53	6.77	170.97	50.39
Xanthoxylum americanum	68.45	21.55	9.16	6.47	97.13	74.21

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 5, Bur oak savanna. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Fraxinus pennsylvanica	0.3022	1.2558	1.1410	0.2866	0	30.18
Parthenocissus quinquefolia	0.3480	1.1239	1.7818	0.3217	0	42.41
Poa pratensis	0.2331	1.8887	0.2642	0.1374	0	22.83
Prunus virginiana	0.3748	1.2558	2.7383	0.5019	0	58.13
Quercus macrocarpa	0.1985	0.9793	1.1709	0.2313	0	37.13
Ribes cynosbati	0.3558	3.1982	1.5495	0.2724	0	40.75
Smilacina stellata	0.3264	2.7730	0.7344	0.2269	0	51.76
Symphoricarpos occidentalis	0.3333	1.8613	0.6966	0.2636	0	16.03
Ulmus americana	0.3826	1.4577	1.5573	0.3245	0	44.21
Xanthoxylum americanum	0.3800	1.9881	1.3608	0.2225	0	46.02

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 5, Bur oak savanna. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Fraxinus pennsylvanica	74.34	15.05	8.84	5.88	60.58	62.03
Parthenocissus quinquefolia	131.72	15.23	9.00	7.06	169.59	67.69
Poa pratensis	78.39	17.45	5.34	2.79	35.50	55.67
Prunus virginiana	125.79	9.44	5.03	10.20	248.90	53.55
Quercus macrocarpa	100.82	24.48	9.08	5.88	342.86	84.83
Ribes cynosbati	87.30	15.32	4.00	6.47	161.74	54.94
Smilacina stellata	114.14	14.19	3.69	4.99	65.00	68.68
Symphoricarpos occidentalis	61.34	16.37	4.55	7.06	140.62	60.32
Ulmus americana	105.41	18.45	7.80	7.21	76.11	77.76
Xanthoxylum americanum	104.46	17.90	8.36	6.47	86.37	50.07

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 6, Bur oak woods. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Acer negundo	0.3861	1.4181	2.2324	0.4435	0	180.08
Corylus americana	0.2072	0.5852	1.6067	0.3928	0	106.44
Fraxinus pennsylvanica	0.2840	1.2857	2.4102	0.3991	0	105.63
Parthenocissus quinquefolia	0.6573	1.8388	2.4870	0.3798	0	187.49
Prunus virginiana	0.3230	1.5234	2.7938	0.5247	0	137.89
Quercus macrocarpa	0.2884	0.9421	1.4366	0.2764	0	69.45
Symphoricarpos occidentalis	0.3740	1.4807	1.4083	0.4188	0	70.19
Thalictrum dioicum	0.4285	2.2739	0.9258	0.2445	0	92.33
Xanthoxylum americanum	0.6287	1.9881	1.5484	0.2748	0	94.17

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 6, Bur oak woods. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Acer negundo	310.36	19.94	5.74	11.71	105.68	106.36
Corylus americana	202.83	20.50	7.16	10.50	346.31	59.42
Fraxinus pennsylvanica	187.10	15.14	10.28	9.30	57.92	63.34
Parthenocissus quinquefolia	325.31	18.91	9.64	10.66	152.54	55.59
Prunus virginiana	214.33	11.43	4.16	11.56	247.95	79.67
Quercus macrocarpa	156.13	23.59	10.04	6.92	301.31	90.43
Symphoricarpos occidentalis	133.01	24.78	6.85	9.60	63.23	90.26
Thalictrum dioicum	183.30	44.62	14.23	7.36	48.22	47.88
Xanthoxylum americanum	182.15	21.36	10.36	7.81	85.03	47.72

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 10, Aspen oak woods. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Amelanchier humilis	0.3748	1.5790	1.3549	0.4037	0	24.72
Corylus americana	0.1925	0.7483	1.3205	0.3615	0	50.37
Crataegus rotundifolia	0.2573	1.1491	1.3199	0.3648	0	40.31
Elymus canadensis	0.3463	2.1933	0.2332	0.1256	0	6.59
Parthenocissus quinquefolia	0.3861	1.5447	1.8803	0.3149	0	79.64
Prunus virginiana	0.3377	1.5888	2.8700	0.4704	0	61.13
Quercus macrocarpa	0.2305	0.9371	1.1445	0.2733	0	30.85
Rosa blanda	0.2892	1.2325	1.4855	0.3882	0	37.79
Smilacina stellata	0.2322	3.6689	0.8866	0.3245	0	41.41
Symphoricarpos occidentalis	0.3126	2.1442	0.8632	0.2944	0	17.25
Viburnum rafinesquianum	0.2503	1.7612	1.4071	0.4157	0	137.89

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 10, Aspen oak woods. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Amelanchier humilis	64.58	42.75	10.12	9.45	409.08	51.93
Corylus americana	91.85	19.38	11.48	9.60	418.15	48.29
Crataegus rotundifolia	89.02	34.84	9.32	7.51	60.13	52.17
Elymus canadensis	53.64	30.84	19.60	3.67	31.13	41.03
Parthenocissus quinquefolia	182.32	44.62	65.95	7.06	201.68	53.88
Prunus virginiana	113.34	18.27	18.70	9.60	322.25	65.23
Quercus macrocarpa	76.52	29.16	23.55	7.51	391.01	47.24
Rosa blanda	103.67	14.02	28.35	7.66	150.24	50.47
Smilacina stellata	80.88	14.71	18.37	7.06	53.07	52.74
Symphoricarpos occidentalis	58.41	23.10	9.80	6.62	135.15	51.61
Viburnum rafinesquianum	116.05	52.21	8.52	11.71	226.60	57.79

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 11, Prairie. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Amorpha canescens	0.1096	0.7226	1.1755	0.2131	0	59.33
Andropogon gerardi	0.0872	1.0164	0.3634	0.1325	0	18.38
Andropogon scoparius	0.0863	0.9624	0.4175	0.1291	0	23.52
Elymus canadensis	0.0631	0.8743	0.2530	0.0637	0	42.19
Heliopsis helianthoides	0.1139	2.1902	2.2404	0.6130	0	121.73
Liatris aspera	0.0639	1.2857	1.2205	0.2315	0	48.30
Petalostemum purpureum	0.0760	0.9692	1.6922	0.1978	0	32.85
Sorgastrum nutans	0.0863	1.0080	0.4669	0.0916	0	34.23
Veronicastrum virginicum	0.0777	1.2558	0.7701	0.3590	0	63.31
Zizia aptera	0.1346	2.3289	2.0954	0.2845	0	125.88

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 11, Prairie. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Amorpha canescens	107.15	15.84	5.74	6.47	61.46	48.29
Andropogon gerardi	58.41	15.84	5.34	4.25	11.56	39.42
Andropogon scoparius	74.19	11.19	5.18	3.96	21.10	38.62
Elymus canadensis	98.77	15.58	2.19	4.99	23.71	46.35
Heliopsis helianthoides	161.18	12.67	6.61	12.62	29.38	142.40
Liatris aspera	71.08	41.94	4.79	5.43	39.88	48.29
Petalostemum purpureum	55.03	22.51	4.16	4.84	35.50	47.15
Sorgastrum nutans	85.26	18.18	2.82	4.11	36.81	39.02
Veronicastrum virginicum	103.35	13.25	8.60	8.85	20.23	42.08
Zizia aptera	151.58	46.40	5.82	8.26	53.51	46.19

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 12, Bur oak woods. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Acer negundo	0.4813	1.6980	1.6790	0.3307	0	138.03
Corylus americana	0.2512	0.9726	2.1856	0.5828	0	144.38
Elymus canadensis	0.3697	2.7223	0.3998	0.1459	0	23.13
Fraxinus pennsylvanica	0.4077	1.4856	1.2391	0.3304	0	76.59
Parthenocissus quinquefolia	0.4155	1.9337	1.7198	0.4268	0	155.04
Populus tremuloides	0.2547	1.4790	1.7372	0.3191	0.0209	49.22
Prunus virginiana	0.4424	1.5921	2.4430	0.4276	0	77.98
Quercus macrocarpa	0.1899	0.0181	1.3106	0.2830	0	56.35
Symphoricarpos occidentalis	0.3506	2.4901	0.9320	0.3202	0	38.55
Tilia americana	0.3368	1.8983	2.3434	0.4669	0	80.53
Uvularia grandiflora	0.3005	2.4604	1.0161	0.4230	0	105.10
Viburnum rafinesquianum	0.2970	1.7012	1.2478	0.4982	0	141.97
Xanthoxylum americanum	0.4363	2.6065	1.3304	0.2125	0	85.29

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 12, Bur oak woods. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Acer negundo	261.74	19.94	7.24	8.41	103.42	72.55
Corylus americana	225.38	19.28	9.24	13.68	412.60	67.36
Elymus canadensis	67.36	24.48	6.61	4.40	33.75	50.96
Fraxinus pennsylvanica	148.01	19.28	26.78	7.51	64.12	47.96
Parthenocissus quinquefolia	250.18	13.93	10.76	10.50	118.33	60.81
Populus tremuloides	88.71	149.98	10.12	6.47	46.90	66.79
Prunus virginiana	126.43	10.39	4.87	8.70	108.83	87.17
Quercus macrocarpa	107.47	24.38	9.96	6.62	245.57	63.67
Symphoricarpos occidentalis	84.17	19.84	7.09	7.06	94.43	47.80
Tilia americana	147.20	17.72	11.08	8.41	60.58	72.55
Uvularia grandiflora	169.84	28.02	10.20	9.90	58.37	34.78
Viburnum rafinesquianum	204.16	39.99	7.48	12.01	117.42	49.09
Xanthoxylum americanum	151.58	22.61	14.87	6.32	64.12	54.04

Basis: One composite sample based on 2–6 selected individuals per species.

Stand 13, Bur oak woods. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Acer negundo	0.4112	1.4527	1.4761	0.2924	0	48.41
Actaea rubra	0.4025	2.8588	1.2148	0.2908	0	63.19
Actaea rubra (sample 2)	0.4155	3.2402	1.2646	0.3031	0	89.97
Amelanchier sanguinea	0.3480	1.1608	1.4171	0.3887	0	41.41
Bromus inermis	0.2832	2.4760	0.3030	0.1531	0	8.19
Corylus americana	0.2132	0.7705	1.3743	0.4533	0	41.08
Crataegus rotundifolia	0.2685	1.0669	1.5561	0.3300	0	38.44
Parthenocissus quinquefolia	0.4060	1.4692	1.7006	0.3277	0	74.70
Populus tremuloides	0.1925	0.8709	1.0883	0.2487	0.0167	29.50
Prunus virginiana	0.5021	1.3438	2.6735	0.5009	0	59.45
Quercus macrocarpa	0.2607	0.9167	0.8805	0.2281	0	28.99
Ribes americanum	0.4476	1.8565	1.9849	0.3488	0	66.00
Rosa arkansana	0.3325	1.3272	1.1588	0.3672	0	33.27
Smilacina stellata	0.3835	3.2462	0.8165	0.2817	0	55.16
Symphoricarpos occidentalis	0.4069	1.9449	0.7525	0.3261	0	16.50
Viburnum rafinesquianum	0.3186	1.7223	1.1158	0.4318	0	74.44

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 13, Bur oak woods. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Acer negundo	98.93	19.10	13.09	7.06	43.83	54.77
Actaea rubra	110.17	13.42	8.28	6.32	32.00	41.67
Actaea rubra (sample 2)	146.07	13.34	9.40	6.47	29.38	44.01
Amelanchier sanguinea	81.98	43.92	7.48	8.26	107.48	48.77
Bromus inermis	38.22	20.13	21.41	4.40	49.54	34.70
Corylus americana	82.13	24.18	15.93	10.20	148.41	62.44
Crataegus rotundifolia	73.41	26.38	6.37	7.51	19.80	30.07
Parthenocissus quinquefolia	180.01	15.23	10.92	7.36	88.16	47.07
Populus tremuloides	70.93	103.12	8.68	5.29	39.00	38.22
Prunus virginiana	103.83	15.23	7.48	9.75	120.14	72.14
Quercus macrocarpa	87.77	45.09	50.75	4.99	225.66	63.02
Ribes americanum	116.69	13.68	5.74	8.26	59.69	45.22
Rosa arkansana	86.36	13.00	8.84	7.81	54.83	56.16
Smilacina stellata	109.05	11.43	7.32	7.36	37.69	34.30
Symphoricarpos occidentalis	50.58	26.28	7.40	7.51	60.58	58.52
Viburnum rafinesquianum	131.56	58.83	9.00	9.75	128.77	58.19

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 14, Prairie. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Andropogon gerardi	0.0838	0.6712	0.2296	0.3004	0	7.76
Andropogon scoparius	0.0803	0.6901	0.2657	0.3541	0	16.31
Apocynum sibiricum	0.1243	0.9557	1.1882	0.6206	0	24.52
Liatris ligulistylis	0.0424	0.6076	0.8805	0.5645	0	22.05
Petalostemum purpureum	0.0682	0.6437	2.0654	0.4310	0	28.47
Salix humilis	0.1226	0.6351	1.1095	0.4733	0	22.93
Sorgastrum nutans	0.0656	0.8557	0.1737	0.1875	0	12.65
Thalictrum dasycarpum	0.0708	0.4883	0.8387	0.5247	0	24.32
Zizia aptera	0.1277	1.2891	1.8979	0.7146	0	50.60

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 14, Prairie. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Andropogon gerardi	42.33	30.21	3.45	7.06	10.26	17.41
Andropogon scoparius	62.26	13.76	2.35	6.77	18.93	22.14
Apocynum sibiricum	61.49	17.81	6.85	12.62	53.95	48.29
Liatris ligulistylis	49.51	36.94	6.53	11.11	33.75	46.67
Petalostemum purpureum	35.19	18.18	4.00	8.26	28.51	43.12
Salix humilis	47.21	10.23	5.26	9.00	28.07	26.26
Sorgastrum nutans	55.64	27.20	1.49	4.99	17.19	21.04
Thalictrum dasycarpum	47.67	33.42	4.71	10.96	44.27	41.75
Zizia aptera	87.77	50.37	5.26	13.07	44.27	41.27

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 15, Bur oak savanna. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Amorpha canescens	0.1925	0.8029	0.6417	0.1609	0	10.09
Andropogon gerardi	0.1864	1.2990	0.2703	0.1101	0	9.22
Andropogon scoparius	0.1605	0.9354	0.2525	0.0774	0	8.19
Juniperus horizontalis	0.1709	0.8489	1.0752	0.2586	0	72.19
Liatris aspera	0.1053	1.0703	1.0076	0.3470	0	23.43
Populus tremuloides	0.2020	0.8862	0.9528	0.2344	0.0336	18.19
Quercus macrocarpa	0.2132	0.8675	0.8287	0.1980	0	25.42
Salix humilis	0.1977	0.9506	0.8821	0.2121	0	26.03
Smilacina stellata	0.4121	2.4167	0.8978	0.2931	0	55.28

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 15, Bur oak savanna. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Amorpha canascens	61.80	25.28	9.00	4.25	92.64	36.14
Andropogon gerardi	56.10	26.28	4.87	2.93	17.63	14.19
Andropogon scoparius	45.23	18.18	3.92	1.91	20.67	20.17
Juniperus horizontalis	151.74	20.03	3.76	7.81	78.78	21.67
Liatris aspera	54.87	56.94	4.95	7.36	89.06	47.40
Populus tremuloides	56.72	188.02	8.36	5.73	72.11	46.99
Quercus macrocarpa	69.69	19.38	7.72	4.40	203.09	46.99
Salix humilis	63.65	104.44	6.85	3.81	53.95	27.13
Smilacina stellata	96.57	19.10	2.43	7.36	49.54	33.50

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 16, Aspen-oak woods. Plant analyses.

Species	P(%)	K(%)	Ca(%)	Mg(%)	Na(%)	Al(ppm)
Amelanchier alnifolia	0.2443	1.2458	1.3047	0.5181	0	32.11
Cornus racemosa	0.2400	0.6832	1.9660	0.4726	0	38.44
Corylus americana	0.1968	0.5679	1.6025	0.4881	0	59.09
Elymus canadensis	0.1139	1.5970	0.2170	0.0986	0	5.84
Maianthemum canadense	0.2331	2.5709	0.9799	0.4627	0	52.70
Populus tremuloides	0.1623	1.0534	1.4761	0.3150	0	27.35
Prunus virginiana	0.1683	1.1591	2.8650	0.6351	0	57.41
Quercus macrocarpa	0.1838	0.7824	0.9855	0.2923	0	30.33
Smilacina stellata	0.1838	2.6375	1.2176	0.4800	0	48.87
Thalictrum dasycarpum	0.2210	1.6329	0.7679	0.3274	0	16.87
Veronicastrum virginicum	0.1519	2.0249	1.2466	0.5948	0	37.46
Viburnum rafinesquianum	0.1640	1.7093	1.3825	0.5364	0	79.77

Basis: One composite sample based on 2-6 selected individuals per species.

Stand 16, Aspen-oak woods. Plant analyses, cont.

Species	Fe(ppm)	Zn(ppm)	Cu(ppm)	Mo(ppm)	Mn(ppm)	B(ppm)
Amelanchier alnifolia	89.02	8.44	7.24	9.60	97.13	34.22
Cornus racemosa	78.86	8.67	5.10	9.00	35.94	21.35
Corylus americana	127.39	18.64	7.56	9.75	116.97	60.07
Elymus canadensis	37.77	7.03	3.61	1.76	19.36	13.96
Maianthemum canadense	110.80	11.35	6.21	10.05	37.25	35.90
Populus tremuloides	77.92	36.16	8.76	5.14	41.63	74.21
Prunus virginiana	106.68	7.99	6.05	11.56	52.19	60.89
Quercus macrocarpa	89.65	24.38	8.12	6.02	106.58	66.95
Smilacina stellata	107.15	6.66	5.66	9.45	24.58	36.70
Thalictrum dasycarpum	51.04	12.34	9.24	7.36	23.71	34.70
Veronicastrum virginicum	84.17	9.60	12.77	10.96	27.20	27.13
Viburnum rafinesquianum	152.23	15.05	6.77	10.20	61.90	75.53

Basis: One composite sample based on 2-6 selected individuals per species.

5.5 Instrument Construction

Details which are obvious from the accompanying photos and drawings (or which are of minor importance) are omitted in the discussion of individual instruments. The mention of brand names, companies, or trademarks does not constitute endorsement but is for informative or clarification purposes only.

5.51 Solar Radiometer

This instrument was constructed to measure the components of solar radiation. Total solar radiation is measured by orienting the instrument horizontally with the glass dome skyward (Fig. A-1); diffuse solar radiation is measured by employing the shade band (Fig. A-2); direct solar radiation is, then, the difference of these two measurements. Reflected solar radiation is measured by orienting the instrument horizontally with the glass dome groundward (Fig. A-3).

The instrument consists of three main components: the instrument housing, the glass dome, and the thermopile. The housing was milled from plexiglas (cast acrylic plastic) according to the dimensions shown in Fig. A-4. (The dimensions were determined by the availability of suitable glass domes.) Plexiglas was chosen because it is light in weight, has a low thermal conductivity, and it machines well. Although it has a high thermal expansion (compared to aluminum and other metals), within normal working temperatures (of the completed instrument) this expansion is negligible. Construction screws were 6/32 brass. Polished aluminum discs and tape (3M Scotch aluminum

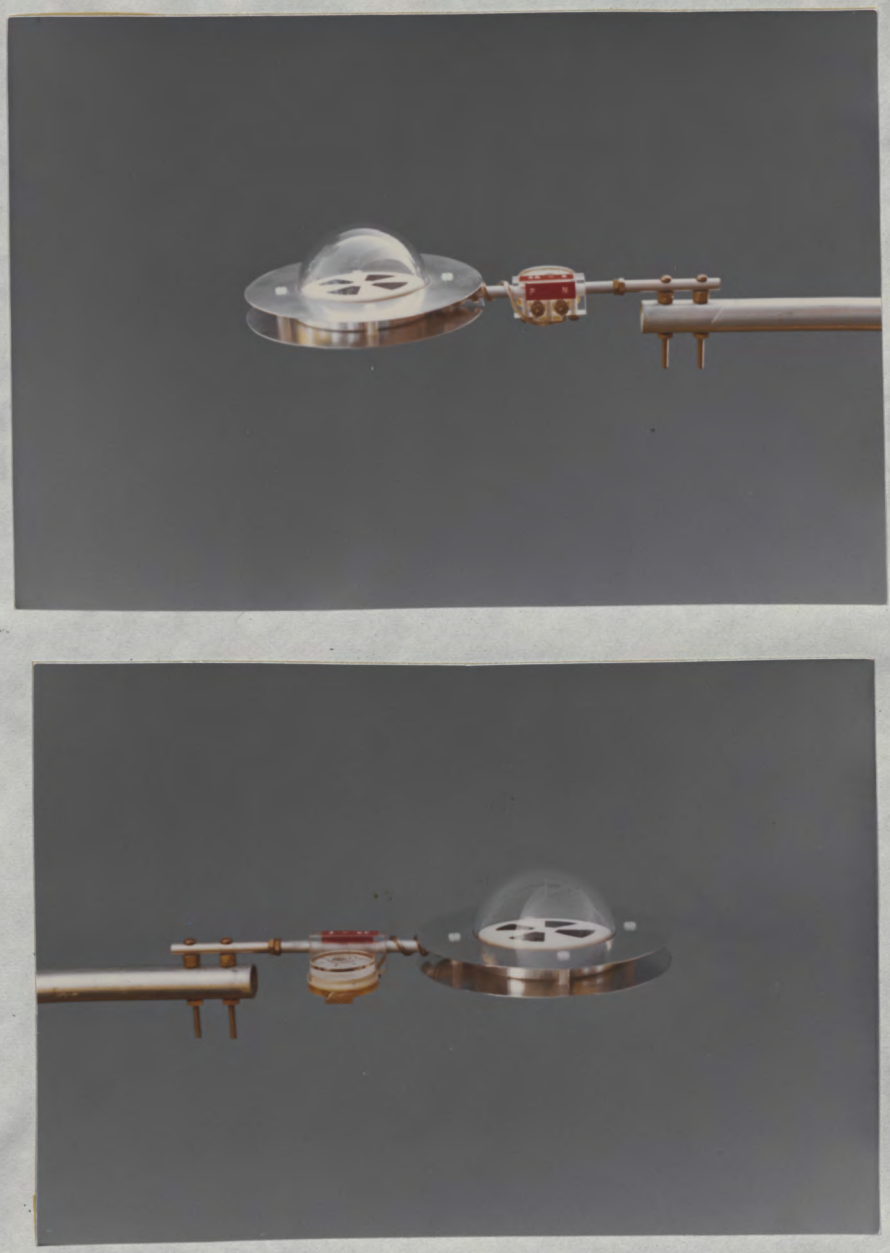

Figure A-1. Photo of solar radiometer in position for sensing total solar radiation.

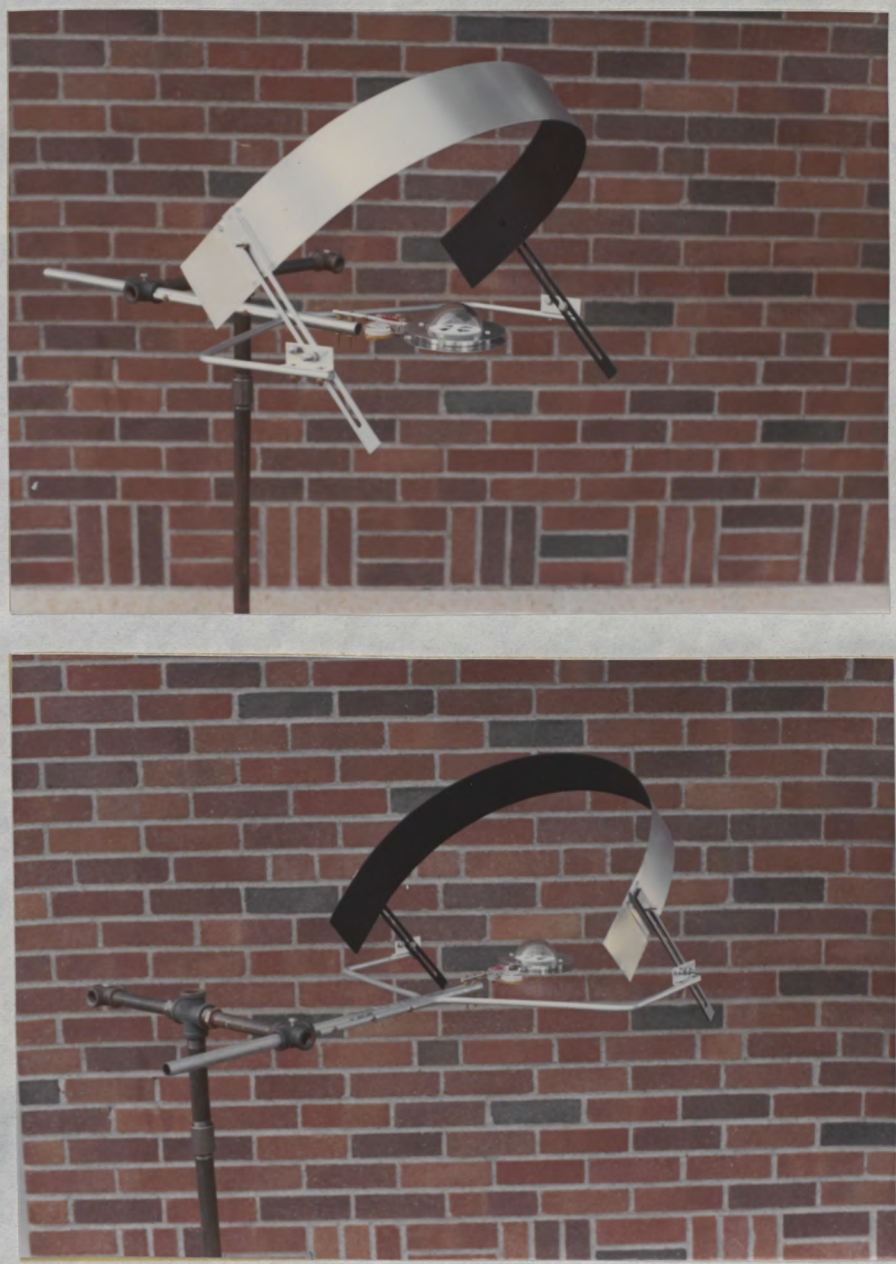

Figure A-2. Photo of solar radiometer with shade band in place for sensing diffuse solar radiation.

Figure A-3. Photo of solar radiometer in inverted position for sensing reflected solar radiation.

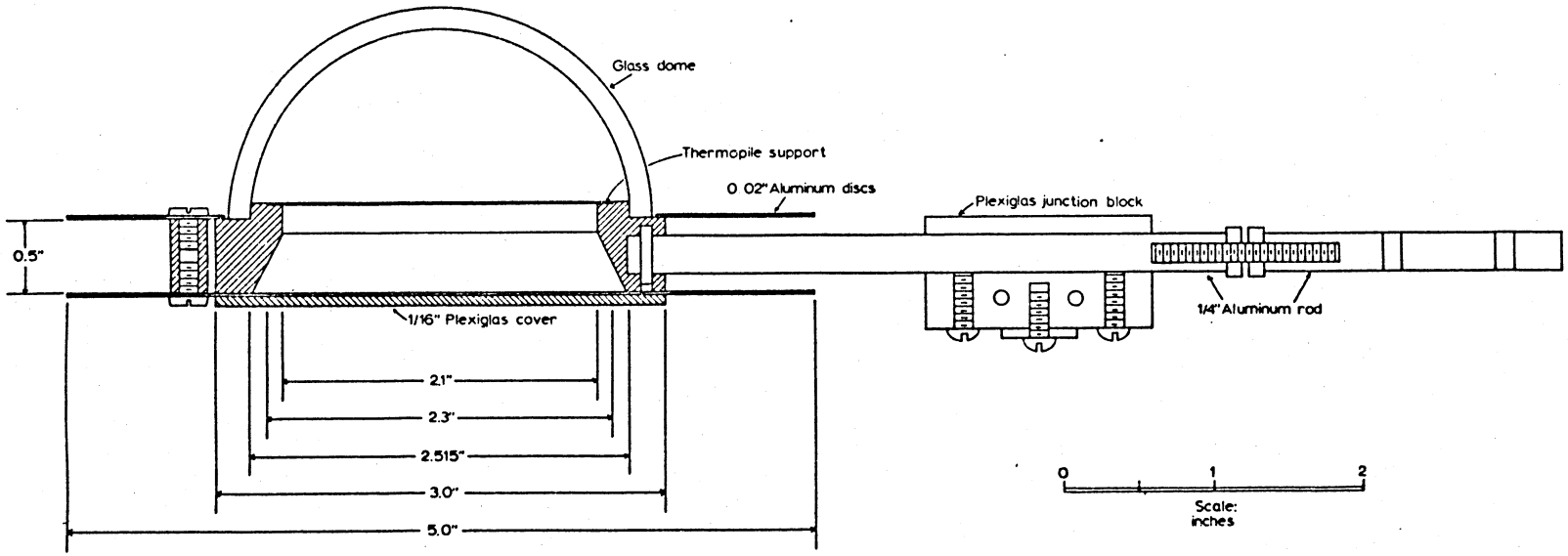

Figure A-4. Construction detail of the solar radiometer, side view. Compare the drawing with Figs. A-1, A-2, and A-3.

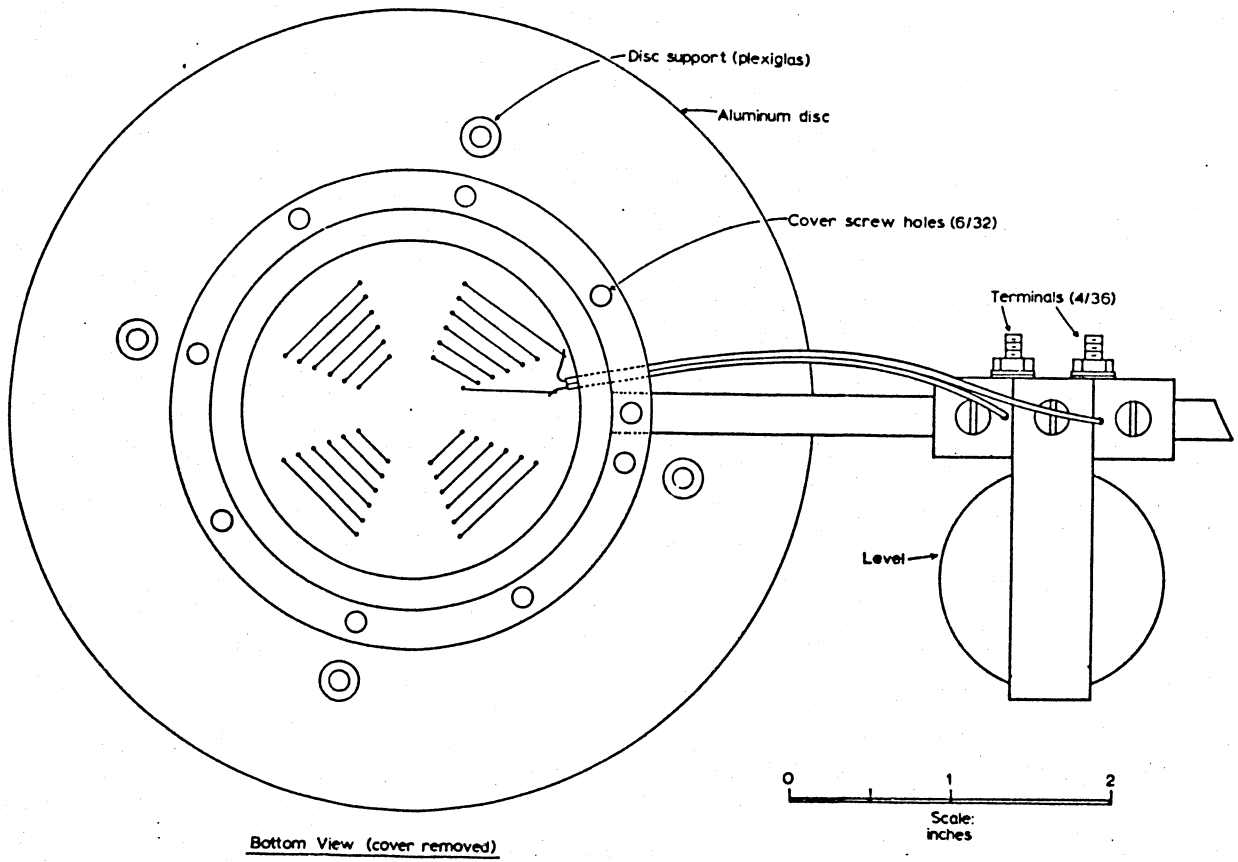

Figure A-4, cont. Construction detail of the solar radiometer, bottom view. Note the thermopile connection (soldered joints).

tape) (Figs. A-1 and A-4) were used as radiation shields, utilizing the very high reflectivity of polished aluminum (Reifsnyder and Lull, 1965). Housing surfaces not protected by polished aluminum were painted with 3M white Velvet Coating (Nextel, 101-A10), utilizing its high reflective properties. Aluminum rod was used for the instrument handle because of its high strength and light weight. As shown in Figs. A-1 and A-4, the handle was constructed in two parts, connected by a bolt, to aid in instrument orientation. A terminal block of plexiglas (because it has very low electrical conductivity) was provided as a convenience; 4/36 brass bolts were used as terminals. A level was attached to the instrument to provide ease in leveling.

The glass dome (2.9 inches in diameter) was purchased from Kahl Scientific Instrument Corporation (El Cajon, CA). The dome is ground and polished and is transparent to light in the 0.28 to 2.80 micron wavelength range.

The thermopile consists of 48 copper-constantan junctions, 24 each under the black and white surfaces (Fig. A-1). The spirally arranged junctions are connected in series as shown in Fig. A-5 (design form Szeicz, 1966). The thermopile support consists of a piece of phenolic 2.29 inches in diameter and 0.010 inches thick. The phenolic has a low thermal and electrical conductivity. Since the phenolic is manufactured with a high surface gloss, it was lightly sanded to remove the gloss and provide better paint adhesion.

Constantan wire (42 gauge), used in thermopile construction,

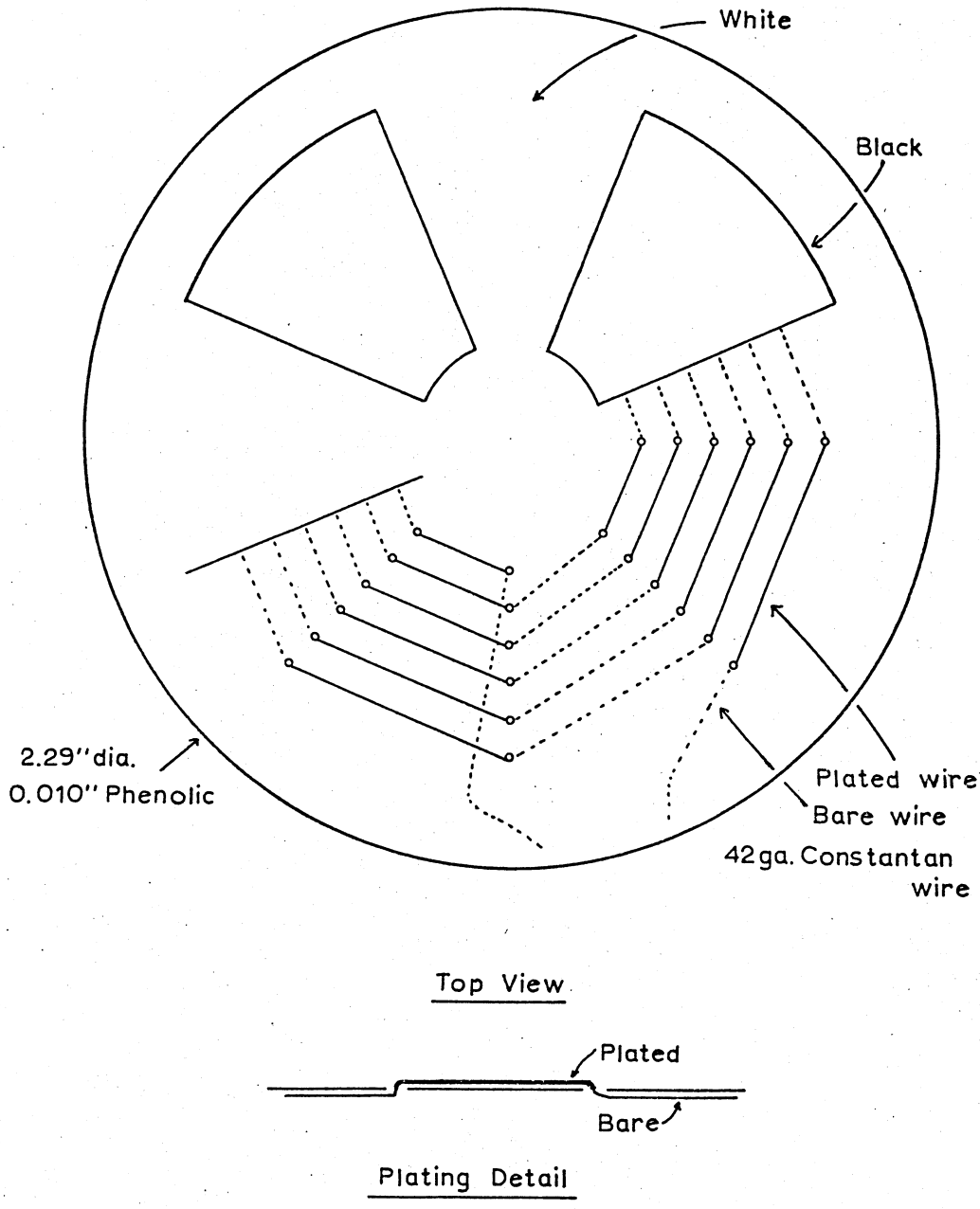

Figure A-5. Construction detail of the solar radiometer thermopile. Note the copper plating only extends partially through the thermopile support.

was woven through the thermopile support (Fig. A-5) and partially copper plated (the portion on the upper surface of the thermopile support) to provide the copper-constantan junctions. The copper was deposited electrolytically (Wilson and Epps, 1920) in a plating bath consisting of 200 g. of $CuSO_4$, 40 g. H_2SO_4 (1N), and 4 l. H_2O (Szeicz, 1965). A 1½ volt dry cell battery was used as the current source, with a resistance of about 550 ohms across the plating bath. A piece of 12 gauge solid copper wire placed in a plastic tube of slightly larger diameter was used as the source of copper (Szeicz, 1965); the amount of copper wire exposed to the plating solution within the tube determined the resistance across the plating bath. Prior to plating, the constantan wire on the underside of the thermopile support was covered with a clear fingernail polish (other high quality varnish may be used) at the holes in the thermopile support (Fig. A-5). (The varnish should extend about half way through the thermopile support, when it is of the proper consistency.) Then a piece of 32 gauge copper wire was woven through the remaining bare constantan wire on the underside of the thermopile support. This copper wire provided the connection to the current source. Since constantan wire has a very high resistance (in comparison with many other metals), a close coupling of the area to be plated with the current source was necessary. Next, the wire to be plated (upper surface of the thermopile) was cleaned with acetone and then carbon tetrachloride. (Acetone must be used sparingly to clean any stray fingernail polish from surfaces to

be plated, such as near the holes in the thermopile support.) Finally, in preparation for plating, the lower surface of the thermopile support was coated with paraffin to completely cover all constantan wire. The thermopile was then immersed in the plating bath for 1½ hours. Following plating, the deposited copper was examined under 10–20X magnification for any anomalies or discontinuities in the plating. Extreme care must be taken in cleaning the wire to be plated; no air bubbles can be on the wire in the plating bath. (The latter may be avoided by slight agitation of the thermopile in the plating bath following immersion.) The paraffin was removed from the thermopile by immersion in three successive baths of boiling tertiary-butyl alcohol. The copper connection wire was then removed from the underside of the thermopile. The upper surface of the thermopile was spray painted with 3M Velvet Coating (two light, even coats) as shown in Fig. A-5 (black, Nextel, 101-C10; white, Nextel, 101-A10). Templates made of Herculene drawing film were used to aid in the painting. The thermopile output was tested prior to cementing into the radiometer housing. Thermopile lead wires were then soldered to the external lead. When the instrument was assembled, silicone seal (Dow Corning) was used to hold the glass dome in place. Prior to sealing the lower part of the instrument, a small bag of silica gel was enclosed to prevent any moisture condensation on the instrument interior. The lower cover (since it is removable) was sealed with a non-hardening silicone compound (Dow 3 compound), with the instrument in an

environment of low humidity (75°F, 31% r.h.).

The instrument was designed to incorporate the beneficial parts of several commercial instruments. Catalogs of instruments were consulted to prepare the basic design. Also, the articles by Monteith (1959a), Norris and Trickett (1968), and Szeicz, Monteith, and dos Santos (1964) were used in formulating ideas. The radial arrangement of black and white surfaces (Fig. A-1) was chosen over the concentric pattern of the Eppley design, even though the radial pattern is harder to construct, to provide equal areas of black and white absorbing surfaces (in the area of the junction).

The instruments were calibrated by comparing output readings with an Eppley pyranometer of known output. Readings were made on clear days and at times of low as well as high sun altitudes. Regressions of the instrument output on incoming radiation were calculated. Correlations of the readings ranged from 0.9995 to 0.9997 on 5 of the 8 radiometers constructed, and thus it was believed the straight line regression equations were adequate calibration equations for these instruments. On 3 instruments, which utilized glass domes with a slightly different shape, the correlations were 0.9963 to 0.9975. Fourth power polynomials were fitted to the output readings of these instruments to provide better calibration equations.

The shade band (Fig. A-2), used to provide measurements of diffuse solar radiation, was constructed of 0.020 inch aluminum, based on the design by Horowitz (1969). Similar

designs are also shown in Drummond (1964) and Robinson (1966). The basic differences in the Horowitz band and the one constructed, were that a) it was necessary for it to be light in weight, b) portable, and c) adapted to the previously described solar radiometers. The band has a width of 3.5 inches, slightly larger than the solar radiometer dome, and a diameter of 21.65 inches. The band was polished on the outside to provide high reflectivity and painted with the 3M black Velvet Coating on the inside to reduce reflection. A mounting frame was constructed of 3/8 inch aluminum rod, 1/8 X 3/4 inch aluminum bar, and 1 X 1 X 1/16 inch aluminum angle. Further explanation is left to Figs. A-6 and A-7.

There are other methods of constructing shade bands (Radiation Commission of IAM, 1958; Robinson, 1966; Robinson and Stock, 1964), but the one constructed appeared the simplest in construction and adjustments. The band must be adjusted for latitude and time of year, the former dictating the angle of the shade band above the horizontal plane of the radiometer, and the latter being a vertical displacement above the horizontal plane. The radiometer and shade band must be oriented towards true south to provide proper adjustment of the shade ring. Corrections may be applied for the portion of the sky blocked by the shade band (Radiation Commission of IAM, 1958; Robinson and Stock, 1964), but for practical purposes may be ignored.

5.52 Total Radiometer

This instrument was constructed to measure the components

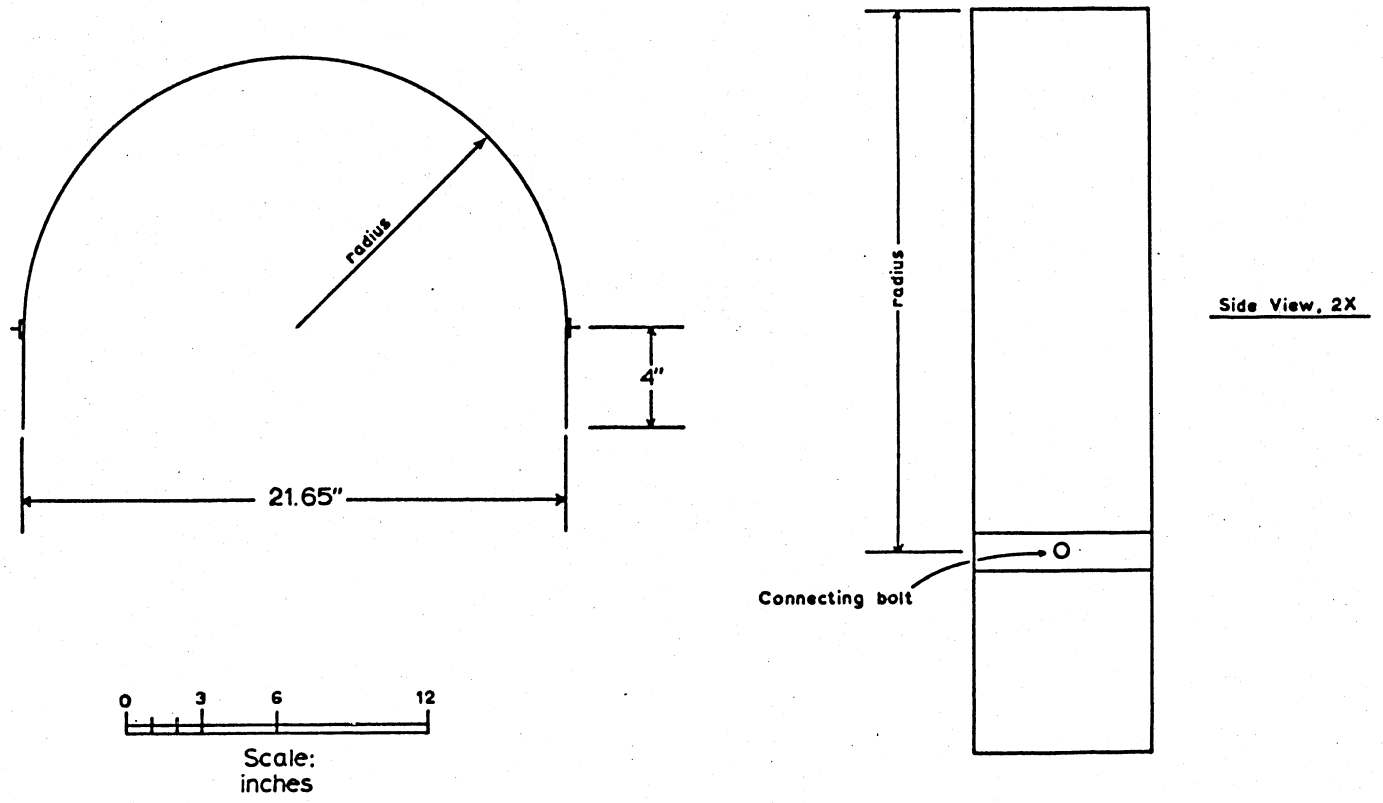

Figure A-6. Construction detail of the solar radiometer shade band. (See also Fig. A-2.)

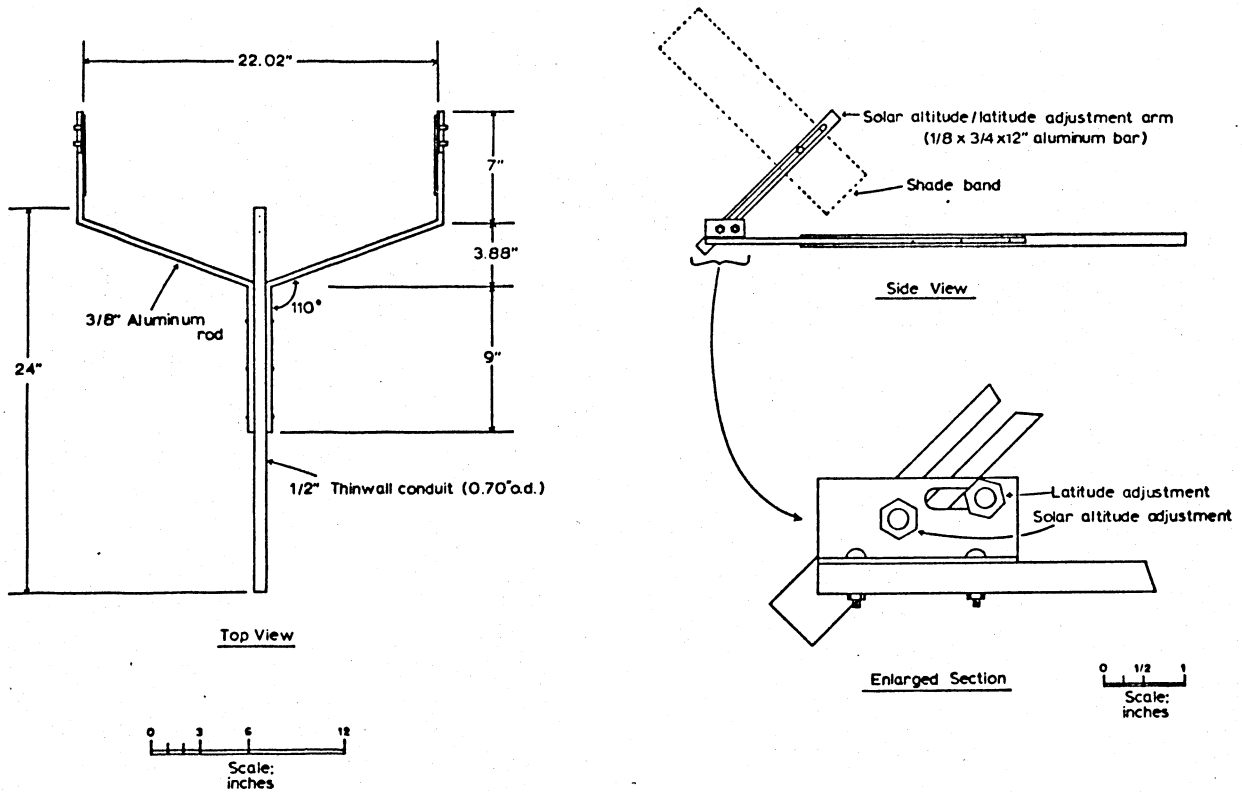

Figure A-7. Construction detail of the solar radiometer shade band frame. (See also Fig. A-2.)

of total radiation, both the downward and upward fluxes. The instrument is oriented horizontally above or below the surface from which a measurement is desired (Fig. A-8). The long-wave component of total radiation may be determined by the subtraction of the short-wave component, as measured with the solar radiometer, from the amount of total radiation. Net radiation is determined by the difference between the downward and upward fluxes of total radiation.

The instrument consists of 4 main components: the instrument housing, the polyethylene shielding domes, the interior thermocouple, and the thermopiles. The housing was milled from plexiglas (for the reasons explained in Sec. 5.51) according to the dimensions shown in Fig. A-9. (Dimensions were determined by the availability of suitable polyethylene domes.) Nylon screws (6/32) were used to connect the two radiometer halves (Fig. A-9). Polished aluminum tape and 3M white Velvet Coating were used for radiation shielding. An aluminum handle, plexiglas terminal block, (brass 4/36 terminal bolts) and level (Figs. A-8 and A-9) were used as explained in Sec. 5.51. Purge ports (Figs. A-8 and A-9) were provided as a means of circulating dry air through the instrument to prevent interior condensation, and to provide a means of inflating the polyethylene domes should they collapse (either from interior air contraction, differential air pressures, or from being touched). The ports consist of two 17 gauge stainless steel hypodermic needles (two in each half of the instrument) cut off so they extend through the side

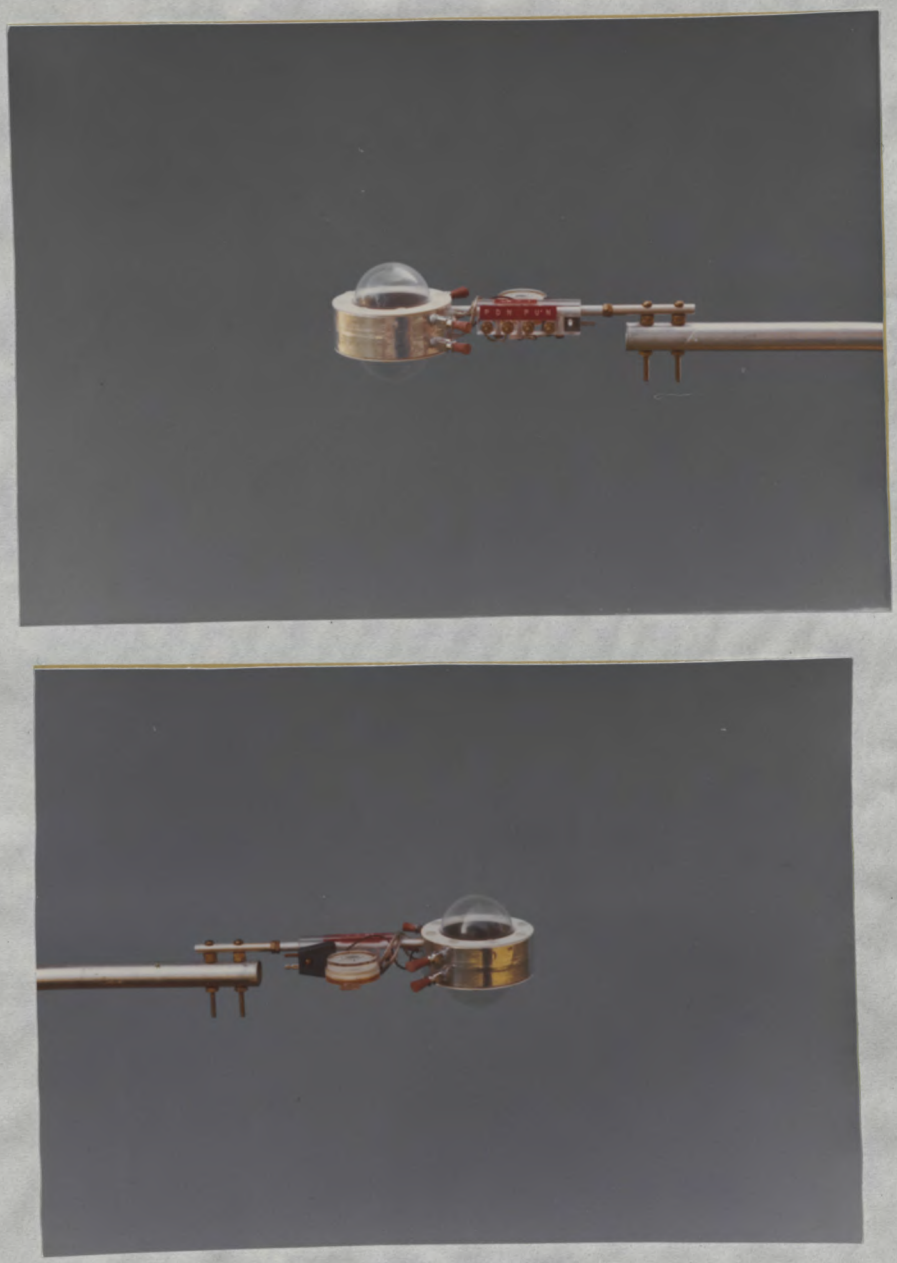

Figure A-8. Photo of total radiometer in its sensing position. Note the purge ports, terminal block, and the removable polyethylene dome clamp ring.

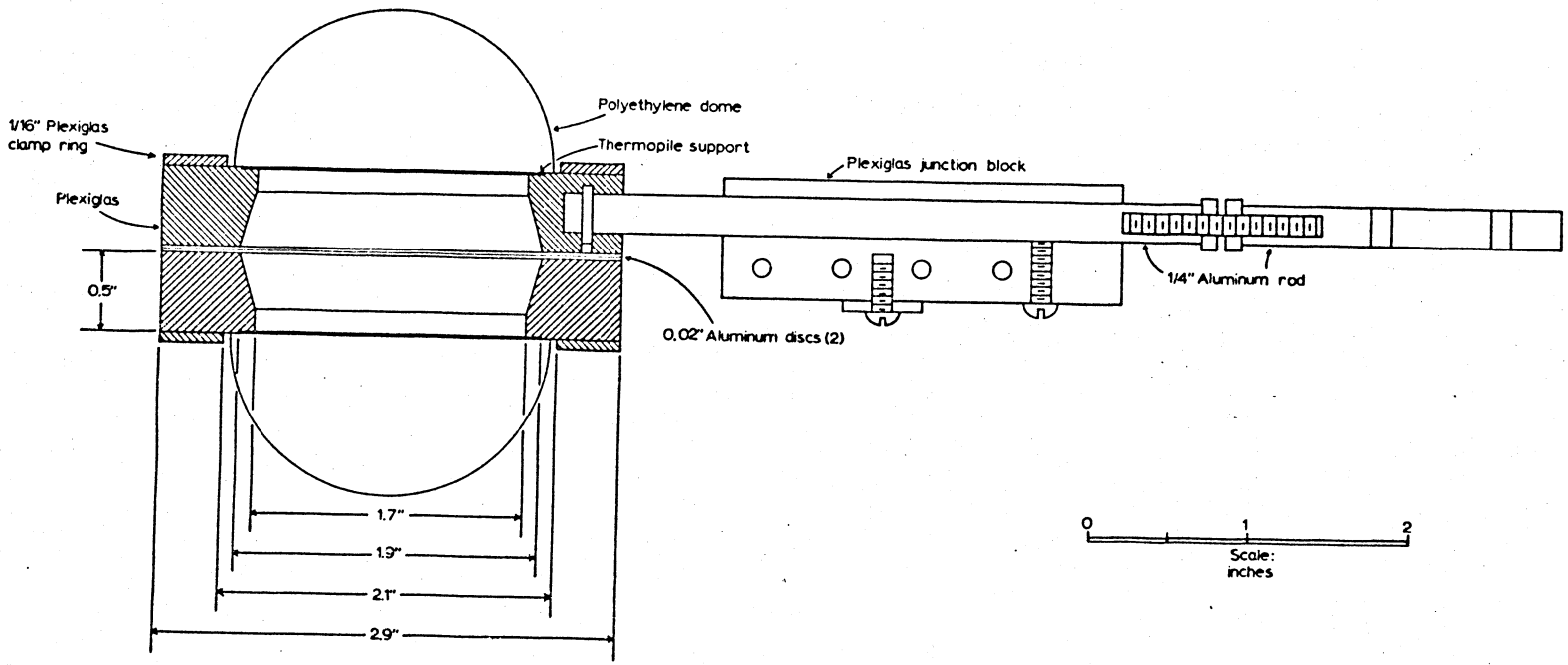

Figure A-9. Construction detail of the total radiometer. Compare the drawing with Fig. A-8.

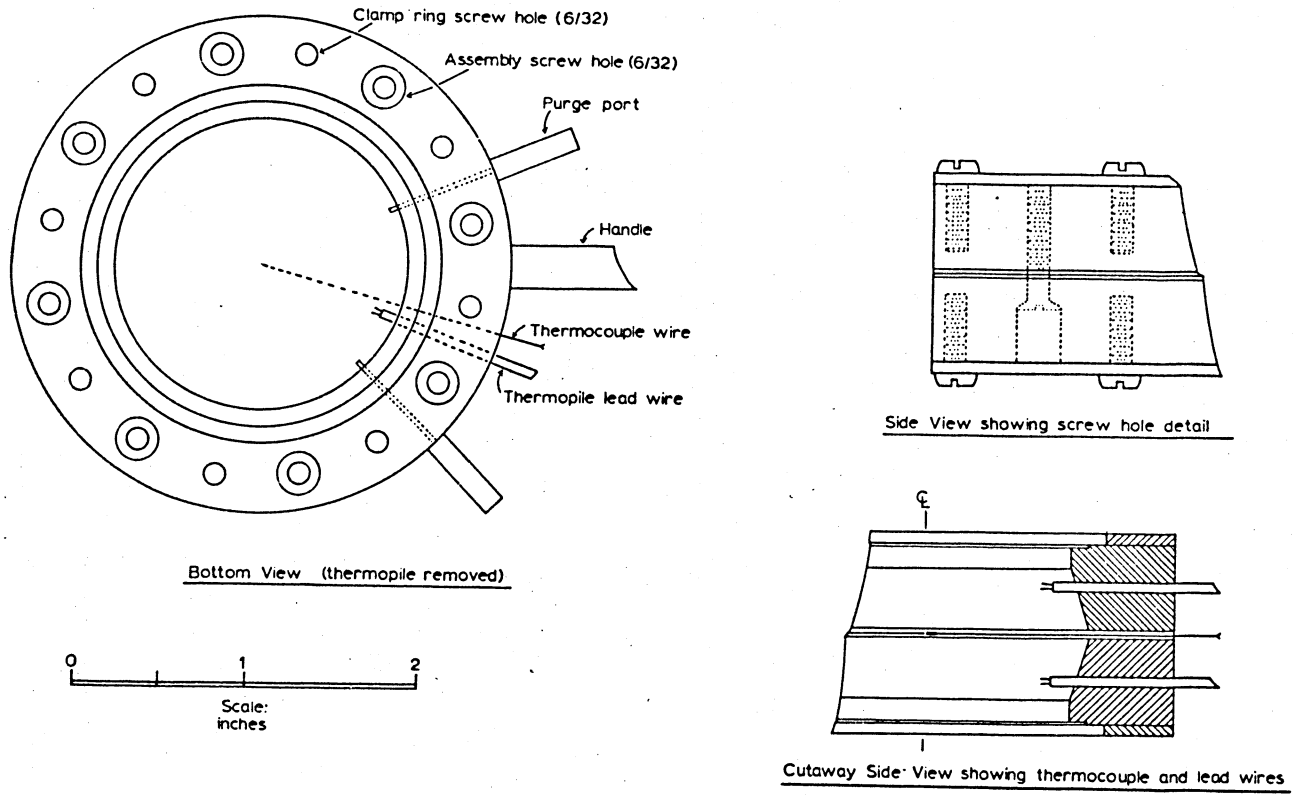

Figure A-9, cont. Construction detail of the total radiometer. Compare the drawing with Figs. A-8 and A-9.

of the instrument (Figs. A-8 and A-9). A rubber inflator, a tube of $CaSO_4$, and a purge port adapter (made from a disposable syringe) were used to provide the dry air source for purging.

Polyethylene domes (C. W. Thornthwaite Associates, Elmer, N. J.) 2.0 inches in diameter were used to shield the thermopiles. Polyethylene has a transparency in the 0.3 to 50 micron wavelength range (with minor exceptions) and therefore is a suitable material for shielding total radiometers (Fritschen, 1963, 1965b; Funk, 1959; Radiation Commission of IAM, 1958; Suomi and Kuhn, 1958; Tanner et al., 1969). Polyethylene cannot be cleaned easily, is easily damaged, and is subject to collapse (as mentioned above), and therefore the instrument was provided with a means of changing the domes. The domes are sealed with a nonhardening silicone seal (Dow 3 compound) and by means of a clamping ring and 8 nylon screws (6/32) (Figs. A-8 and A-9).

To measure the incoming and outgoing fluxes of total radiation, a means of differentiating the fluxes must be used. Normal net radiometers cannot do this. Thus, the total radiometers, as designed here, utilizes two net radiometers, both of which sense the difference in flux between the interior of the instrument and the outside environment. Then, the interior radiation flux is determined by the use of a thermocouple to sense the temperature (Fig. A-9) and by applying the Stefan-Boltzman Law (Kreith, 1965; Munn, 1966; Planck, 1914; et al.). The fluxes toward the instrument were then determined by subtraction.

The thermopiles were constructed from 42 gauge constantan wire, copper-plated to provide 32 junctions connected in series to provide 16 junctions sensing the thermal flux from each direction. Details of the thermopile are shown in Fig. A-10. The thermopile support was made from a piece of phenolic 0.010 inches thick and 1.89 inches in diameter. The constantan wire was woven radially and copper-plated as shown in Fig. A-10. A 32 gauge copper wire was woven under the constantan wire near the outside edge of the thermopile as a current source connection and to reduce the resistance to the area to be plated. Then the constantan wire was cleaned with carbon tetrachloride and the area not to be plated coated with paraffin. The rest of the plating procedure follows that described in the discussion of solar radiometers (Sec. 5.51).

The thermopiles, following plating, were tested, cemented into the radiometer housing, and the lead wires connected to the external leads. The interior of the instrument was painted with the 3M black Velvet Coating, as was the outward facing surface of the thermopile. Except for the rubber plugs of the purge ports and the removable polyethylene domes, the instrument was sealed with silicone seal (Dow Corning).

Calibration was accomplished by comparing output readings with those measured by a ventilated total hemispherical radiometer (Packard Bell) [similar to the instrument shown by MacKay, 1965]. Each half of the total radiometer was calibrated separately. The least squares method was used to fit third

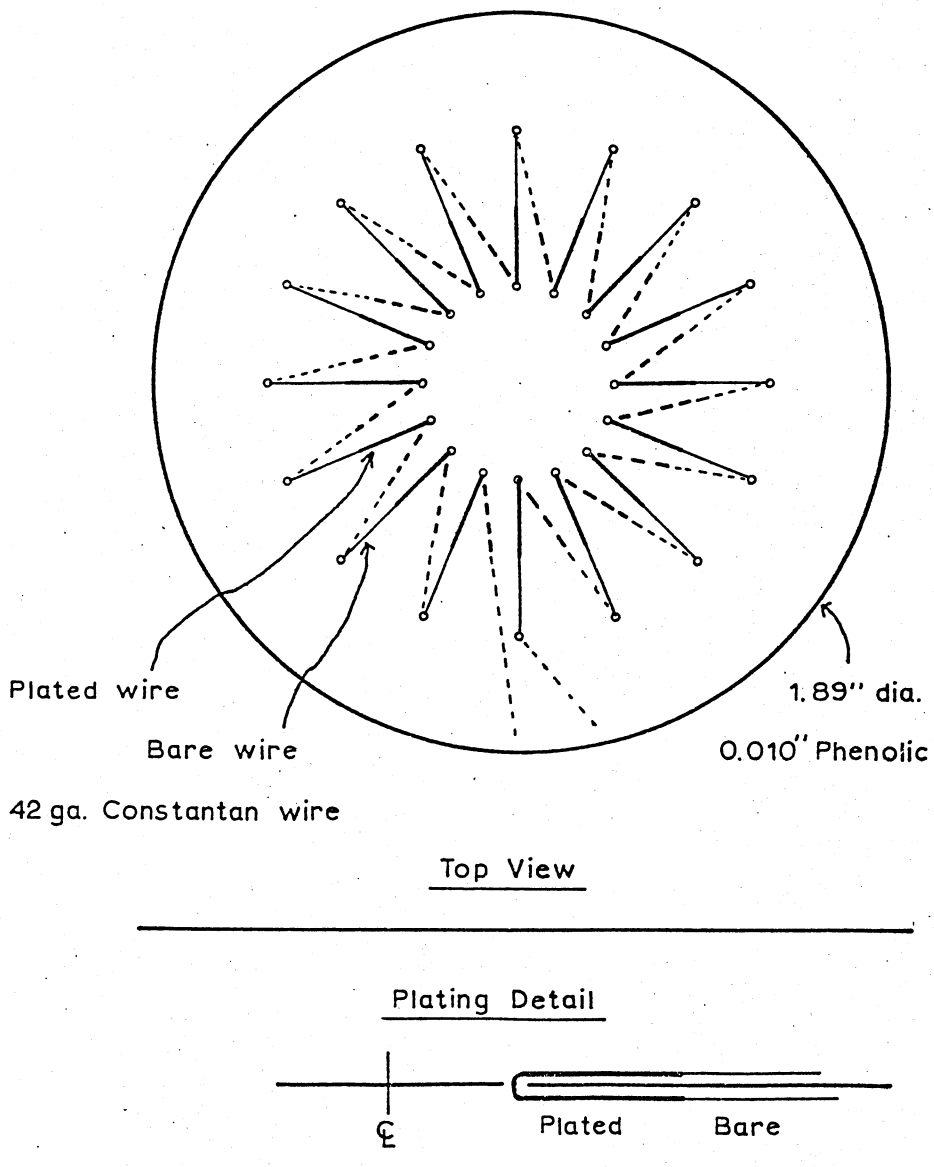

Figure A-10. Construction detail of the total radiometer thermopile (two used per instrument). Note the copper plating extends through the support disc to provide junctions on the upper and lower side of the support.

power polynomials to the data to provide calibration curves. Output of the instruments are approximately 0.2 millivolts per cal cm^{-2} min^{-1} at an air temperature of about 21°C.

5.53 Soil Heat Flux Unit

This instrument (Fig. A-11) was designed to measure the heat flux to and from the soil. The direction of heat flow is determined by whether the output is positive or negative.

Philip (1961) discusses the necessary criteria of a heat flux unit. The designed instrument consists primarily of a non-shielded thermopile. A lead wire with junction block was provided as a convenience. Dimensions of the instrument are shown in Fig. A-12. Basically the thermopile consists of 42 gauge constantan wire copper-plated to form 30 junctions in series alternating between the upper and lower side of the unit. Plating was done as described in Secs. 5.51 and 5.52. The unit was semi-waterproofed using clear fingernail polish (a high quality varnish) and was painted with 3M black Velvet Coating. The design is similar to that of Deacon (1950); alternative (but similar) heat flux plates are described by Fuchs and Tanner (1968) and Hatfield and Wilkins (1950).

Calibration was accomplished by measuring the amount of heat flux through a box of fine sand (the same soil in which the instruments would be used) on a hot plate and by measuring the heat flux unit output. Regressions through the origin (Steel and Torrie, 1960) of heat flux on unit output provided the calibration constants. (Since zero heat flux requires zero

Figure A-11. Photo of the soil heat flux unit, with lead wire and junction block.

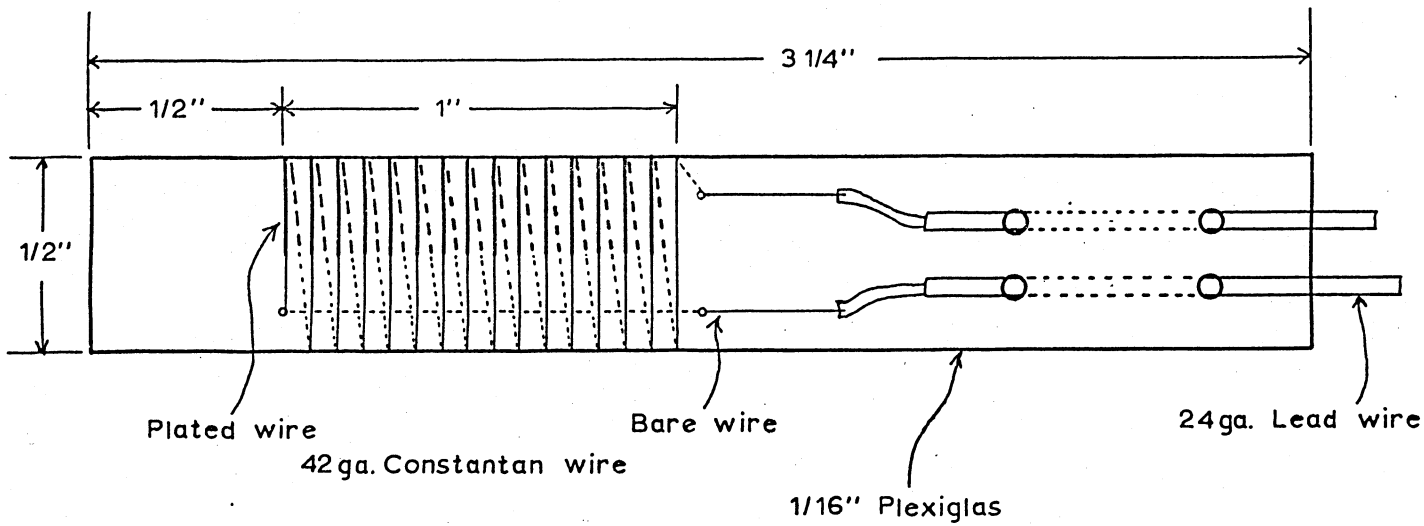

Figure A-12. Construction detail of the soil heat flux unit. Copper plating extends from top center to bottom center to provide junctions on both sides of the unit.

output from the heat flux unit, regressions through the origin were desired.) The equation $G = k\, dt/dz$ (adapted from Rose, 1966), where G (cal cm^{-2} min^{-1}) is the heat flux through the soil, k (cal cm^{-1} min^{-1} $^{o}C^{-1}$) is the thermal conductivity, and dt is the difference in temperature (^{o}C) over the distance dz (cm), was used to determine actual soil heat flux. Thermometers of a known distance apart (with the heat flux unit between them) were used to measure the actual temperature of the sand. Based on the work by De Vries (1963), Kersten (1949), and Van Wijk (1963), and the moisture content of the sand, the thermal conductivity was determined to be 0.03345 cal cm^{-1} min^{-1} $^{o}C^{-1}$ (see also Smith, 1940; Smith and Byers, 1939). Kohnke and Nakshabandi (1964) and Van Wijk and Derksen (1966) discuss some of the factors which affect variability of thermal conductivity.

5.54 Instrument Tower

The instrument tower (Fig. A-13) was designed for the support of the previously described radiometers. The radiometer support arms were made of $\frac{1}{2}$ inch thinwall conduit, the cross arms from $\frac{1}{2}$ inch black pipe, and the uprights from 3/4 inch black pipe. All the essential details can be seen in the photo (Fig. A-13). Cross tees and couplings were used to join the tower sections. The $\frac{1}{2}$ inch cross tees were reamed to accept the $\frac{1}{2}$ inch conduit, and were also drilled and tapped for a locking screw. The tower will also accept other instruments by use of appropriate fittings.

Figure A-13. Photo showing the constructed instrument tower.